# 日　本　国　特　許　庁
PATENT OFFICE
JAPANESE GOVERNMENT

別紙添付の書類に記載されている事項は下記の出願書類に記載されてる事項と同一であることを証明する。
This is to certify that the annexed is a true copy of the following application as filed th this Office.

出願年月日
ate of Application: 1993年12月20日
December 20, 1993

出願番号
plication Number: 平成　5年特許願第320247号
Pat. Appln. No. 5-320247

願人
licant (s): ミノルタ株式会社
MINOLTA CO., LTD.

1994年12月16日
December 16, 1994

特許庁長官
Commissioner,
Patent Office

高島　章
Akira Takashima

出証番号　出証特平06−3066451
Shutsu-sho-No. Shutsu-sho-toku-hei 06-3066451

| | |
|---|---|
| [Document Name] | Petition for Patent |
| [Filing Number by Applicant] | 93122002 |
| [Filing Date] | December 20, 1993 |
| [Destination] | To the Commissioner of the JPO |
| [International Class] | G01B 11/00 |
| [Title of the Invention] | Image Input Camera |
| [Number of Claims] | 4 |
| [Inventor] | |
| [Address] | c/o MINOLTA CAMERA KABUSHIKI KAISHA, Osaka Kokusai Building, 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku, Osaka-Shi |
| [Name] | Eiro FUJII |
| [Inventor] | |
| [Address] | c/o MINOLTA CAMERA KABUSHIKI KAISHA, Osaka Kokusai Building, 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku, Osaka-Shi |
| [Name] | Shigeaki IMAI |
| [Inventor] | |
| [Address] | c/o MINOLTA CAMERA KABUSHIKI KAISHA, Osaka Kokusai Building, 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku, Osaka-Shi |
| [Name] | Toshio NORITA |

| | |
|---|---|
| [Applicant for Patent] | |
| [Identification Number] | 000006079 |
| [Address] | Osaka Kokusai Building, 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku, Osaka-Shi, Osaka |
| [Name] | MINOLTA CAMERA KABUSHIKI KAISHA |
| [Representative] | Osamu KANEYA |
| [Indication of Fee] | |
| [Deposit Account Number] | 012324 |
| [Fee] | 21000 |
| [List of the Accompanying Documents] | |
| [Document] | Specification 1 |
| [Document] | Drawings 1 |
| [Document] | Abstract 1 |
| [Necessity of Proof] | Necessary |

[Document Name] Specification
[Title of the Invention] Image Input Camera
[Scope of Claims for Patent]

[Claim 1] An image input camera, comprising:

input means for inputting image data of an object;

calculating means for calculating, from a plurality of pieces of the image data input by the input means from multiple viewpoints, a coordinate conversion parameter for patching up the plurality of pieces of the image data; and

patch up means for patching up the plurality of pieces of the image data by the parameter obtained by the calculating means.

[Claim 2] The image input camera according to claim 1, wherein the calculating means obtains, as the coordinate conversion parameters for patching up the plurality of pieces of the image data, a rotation angle of the object relative to the input means and a position of a rotation axis of the input means, based on the plurality of pieces of the image data input.

[Claim 3] The image input camera according to claim 1, wherein the calculating means obtains, as the coordinate conversion parameters for patching up the plurality of pieces of the image data, a rotation angle of the object relative to the input means and a position of a rotation axis of the object, based on the plurality of pieces of the image data input.

[Claim 4] The image input camera according to any of claims 1-3, wherein the patch up means performs coordinate conversion of the plurality of pieces of the image data to one coordinate system, based on the coordinate conversion parameter obtained by the calculating means.

[Detailed Description of the Invention]

[Technical Field to Which the Invention Belongs]

The present invention relates to an image input camera that generates image data of an object having a relatively complex shape, and performs image patch up using the image data.

[Prior Art]

Conventionally, among means for recognizing a three-dimensional shape of an object, for example, a light-section method has often been used

as most practical means. With the light-section method, as shown in Fig. 1, an object is irradiated with a slit shaped laser light S, and a slit image of the object 1 corresponding to the slit shaped light S is obtained on the imaging plane of the camera. A spatial coordinate of a point p on the object corresponding to a point p' on the slit is calculated as the coordinate of a crossing point of a plane S formed by the slit shaped light and a straight line L connecting the point p' and the center O of the lens of the imaging device. As such, spatial coordinates of points on the object surface corresponding to the respective points on the slit image are obtained from an image, and three-dimensional information of the entire object is obtained by repeating image input while moving the slit shaped light in a horizontal direction.

A plurality of pieces of image data obtained by the above-described method have conventionally been patched up in accordance with conversion parameters calculated based on the position of the camera or the position of the rotary stage detected with mechanically high precision.

[Problems to be Solved by the Invention]

With the conventional patch up method of a plurality of pieces of image data, it is necessary to detect the position of the camera or the rotary stage with mechanically high precision. To achieve such mechanically high precision, however, the apparatus would be extremely expensive. Further, it would be difficult to use the same in such a rough input environment that an input is made with a hand-held camera or the like.

The present invention has been made to eliminate the deficiencies of the conventional art, and its object is to perform image patch up at a relatively low cost, by inputting a plurality of pieces of image data via multiple viewpoints, calculating relative positions of the input images, and obtaining a conversion parameter of the image data to perform the patch up thereof.

[Means for Solving the Problems]

To achieve the above-described object, an image input camera of the present invention includes input means for inputting image data of an object, means for calculating, from a plurality of pieces of the image data

input from multiple viewpoints, a coordinate conversion parameter for patching up the plurality of pieces of the image data, and means for patching up the plurality of pieces of the image data.

[Function]

According to the configuration of the present invention, relative positions of the images are calculated for the plurality of pieces of image data having been input, a coordinate conversion parameter is obtained therefrom, and coordinate conversion is carried out to perform the patch up processing.

[Embodiments]

Hereinafter, embodiments of the present invention will be described with reference to the drawings.

Firstly, Fig. 2 is a schematic block diagram of the entire apparatus in accordance with the present invention. Briefly stated, the apparatus of the present invention includes a light projecting optical system 2 for irradiating an object 1 with laser beam, which is output from a semiconductor laser 5 and turned into a slit shaped light, and a light receiving optical system 3 for guiding the projected laser beam to imaging sensors 24 and 12. These optical systems are arranged on a same rotary frame 4. In addition to the optical systems, the apparatus includes a signal processing system for processing a signal output from a sensor for generating pitch-shifted images and color images, and a recording device for recording the generated images. In Fig. 2, solid arrows denote flow of electric signals such as image signals, control signals and so on, while dotted arrows denote the flow of projected light. Details of these optical systems will be given later.

An outline of the signal processing system will be described. With respect to an image obtained by a distance image sensor 12, subtraction between an image 18a when slit shaped light is projected and an image 18b when slit shaped light is not projected is performed, and calculation of the position of centroid of the incident light 19, calculation of pitch-shift information 20 and pitch-shift image generating process 21 are performed on the image. The obtained pitch-shifted image is utilized as an output to

an output terminal 50 after NTSC conversion 27, or as digital information to be transferred to an SCSI terminal 49 or an internal recording device 22. The image obtained by a color image sensor 24 is subjected to analog processing 25 and then to color image generating process 26. The resulting color image is utilized as an output to an output terminal 51 after NTSC conversion 28, or as digital information to be transferred to SCSI terminal 49 or recording device 22.

Fig. 3 is a perspective view showing the schematic structure of the entire apparatus.

In this embodiment, a generating system for distance image having 256 points of distance information in the lengthwise direction of the slit shaped light and 324 points of distance information in the scanning direction of the slit will be described as an example. An LCD monitor 41 provides display of a color image formed by color image sensor 24, three-dimensional data stored in an internal or external recording device, various other information, menu for selection, and so on. A cursor key 42, a select key 43 and a cancel key 44 are operating members for setting, for example, various modes from the menu, or for selecting images. A zoom button 45 is provided for changing focal length of the light projecting/light receiving optical systems. An MF button 46 is for manual focusing. A shutter button 47 is for taking a distance image when turned ON in a shutter mode, which will be described later. A drive 48 such as an internal magnet-optic disc (hereinafter referred to as MO), a mini disc (hereinafter referred to as MD) is provided as the storage apparatus for the picked up image. A terminal 49 is, for example, an SCSI terminal for digital input/output of signals of images and the like. A pitched-shifted image output terminal 50 and a color image output terminal 51 are provided for outputting images in the form of analog signals, and the images are provided as NTSC video signals, for example.

The light projecting optical system scans the object by moving a horizontally elongate slit shaped light in upward and downward directions, and the light beam from semiconductor laser 5 is directed to the object through a rotating polygon mirror 7, a condenser lens 10, a light directing

zoom lens 11 and so on. The light receiving optical system picks up an image by means of a light receiving zoom lens 14, a beam splitter 15 and so on, and further by distance image sensor 12 and color image sensor 24 arranged on a light receiving image pickup plane. Details of the optical systems and the imaging system will be given later.

The slit shaped light from the light projecting system is moved downward one pixel pitch by one pixel pitch of the distance image sensor 12, by means of constantly rotating polygon mirror 7, while distance image sensor 12 accumulates one image. The distance image sensor scans the accumulated image information, provides an output, and performs accumulation of the next image. From the image provided at one input, distance information of 256 points in the lengthwise direction of the slit shaped light can be calculated. Further, by repeating the mirror scanning and taking of images 324 times, a distance image consisting of 256 x 324 points is generated.

As for the distance range to the object measured by one slit shaped light, the minimum and maximum measurement distances are limited, and therefore the range of incident light which is the slit shaped light reflected by the object and entering the image pickup device is limited within a certain range. This is because the light projecting system and the light receiving system are arranged apart from each other by a base length (length: 1). This is illustrated in Fig. 4 in which the Z axis represents a direction perpendicular to the image pickup plane for the distance image. The position of the dotted line d is a reference plane for measurement, and the distance from the plane of the device corresponds to d.

Df represents maximum distance for measurement and Dn represents minimum distance for measurement. Now, if the plane cut by the slit shaped light projected from the light projecting system is slit A (SA), the scope on the plane of the image pickup device receiving the slit shaped light reflected by the surface of the object is limited to a closed area Ar, in which a position of projection on the image pickup device of the three-dimensional position of an intersection PAn between the minimum distance Dn for measurement and the slit A is the lowermost point in the figure, and

the projected point on the image pickup device of the three-dimensional position of the intersection Paf between the maximum distance Df for measurement and slit A, projected on the image pickup device with the position of the main point of the image pickup system being the center, is the uppermost point in the figure. Assuming that the light projecting system and the light receiving system have the same positional relation, in the case of slit B (SB), the scope on the plane of the image pickup device is limited to a closed area Br on the image pickup device, in which the point of projection of the intersection PBn of the minimum distance for measurement Dn and slit B is the lowermost position in the figure, and the point of projection of intersection Pbf of the maximum distance for measurement Df and the slit B is the uppermost point in the figure.

Therefore, in the measuring apparatus, the position of the centroid of the laser beam received at 256 lines is calculated based on the input image. More specifically, the position of the centroid is calculated as the amount of deviation from the reference plane for measurement, that is determined based on an object distance output from an auto focus unit and direction of the projected slit shaped light, that is, the time from the start of scanning. The calculation of the amount of pitch shift will be described with reference to Fig. 5. Fig. 5 shows light intensity distribution generated by the slit shaped light directed to the object. The sections at the lower portion of the figure represent areas monitored by each of the elements of the distance image sensor. These sections have numbers 1, 2, 3, 4, ... allotted thereto, starting from the front side. A slit shaped light having very narrow slit width is moved for scanning only by 1 pitch of the distance image sensor by the rotation of polygon mirror 7 while one image is accumulated. Therefore, the light intensity distribution when one image is input corresponds to a rectangular light intensity distribution of which width corresponds to 1 pitch of the distance image sensor.

In order to calculate distance information in the direction of the Z axis for each pixel of the distance image sensor, such a rectangular light intensity distribution having the width of 1 pitch is desirable. When the width of the light intensity distribution becomes wider than 1 pitch, the

distance information measured would be calculated as weighted mean of the intensity of light received at adjacent areas, and hence correct distance information would not be obtained.

Assume that there is a step-shaped object surface such as represented by the dots in Fig. 5, and a slit shaped light is directed from a direction vertical to the plane of the object. The thin rectangular parallelepiped represents the light intensity distribution of the slit shaped light and the hatched area represents the slit-shaped image irradiated by the light beam. When we assume a positional relation in which an optical axis Oxp of the light receiving optical system is provided inclined to the left from an optical axis Oxa of the light projecting system, the light intensity distribution of the received slit shaped light at the light receiving plane would be as shown in Fig. 6, because of a filter, which will be described later. It is desirable to remove fixed light component other than the laser beam component so that the fixed light component is not included in the received light intensity. For this purpose, an image irradiated with the laser beam and an image not irradiated with the laser beam are both input, and the difference therebetween is used. The sections at the lower portion represent respective element regions of the distance image sensor.

In front of the distance image sensor, there is provided an anisotropic optical filter which does not degrade resolution in the lengthwise direction of the received slit shaped light but degrades the resolution in the widthwise direction of the slit shaped light, and by means of this filter, the light intensity distribution having such a Gaussian distribution as shown in Fig. 6 results. With respect to this light intensity distribution, by calculating the centroid of the light intensity distribution from respective sensors for columns 1, 2, 3, 4, ..., the position at which the light is received can be calculated with higher resolution than the pixel pitch. The reason why the width of the slit shaped light incident on the sensor is not narrowed but selected to have the width of about 5 to 6 pixels by using a filter for detecting the position at which the slit shaped light is received is that when the width of the incident slit shaped light becomes narrower than the width of one pixel, the resolution for detecting the position could

be at most the same as the pixel pitch.

Based on the light intensity distribution D1 received by the first column, the position G1 of the centroid of the first column is calculated. In the similar manner, the positions G2, G3, G4, ... of centroid of the second, third, fourth and the following columns are calculated, and thus the centroid of each column is calculated. As shown in the figure, the optical axis of the light projecting system is vertical to the plane of the object. However, the optical axis of the light receiving system is inclined to the left. Therefore, when the object has a step as shown in Fig. 5, the centroid of the higher portion (third and fourth columns) is positioned shifted to the right, with respect to the centroid of the lower portion (first and second columns). Though the distribution D1 of the first column and distribution D4 of the fourth column only are shown in Fig. 6, the distribution D2 of the second column is the same as the distribution D1 of the first column, and the distribution D3 of the third column is the same as the distribution D4 of the fourth column. The relation between the light intensity distribution and the positions of the centroid is represented two dimensionally in Fig. 7. Since the distributions of the first and second columns are the same, the calculated centers of gravities G1 and G2 are detected as the same position. Similarly, since the distributions of the third and fourth columns are the same, the calculated centers of gravities G3 and G4 are detected as the same position.

In this manner, from a slit-shaped image corresponding to one slit, positions of the incident light at 256 points are calculated. By performing similar calculation for the slits directed to 324 directions, 324 images are obtained, and a pitch-shifted image consisting of 256 × 324 points is obtained. The obtained pitch-shifted image consists of only the positional information of the slit shaped light. Therefore, in order to obtain an accurate distance image, calibration (correction) based on a table of detailed data such as lens aberration correction is necessary. Therefore, lens aberration estimated from the focal length f and in-focus position d of the taking lens is calculated, corrected, and distortion in the longitudinal and lateral directions with respect to the camera is corrected. Similar

operation is performed with respect to the color image. The data necessary at that time includes information of various measurement lenses, that is, focal length f and in-focus position d. In the system of the present embodiment, calibration is performed on a computer system, and connection to the measurement apparatus of the present invention (shown in Fig. 3) is provided by SCSI terminal, for example. Alternatively, the data may be shared by using a recording medium such as MO.

In this manner, from the body of the measuring apparatus, color images and pitch-shifted images are provided as digital signals from a terminal such as SCSI terminal, or provided as analog video signals from an output terminal such as BTSC terminal. Data necessary for calibration are provided to the computer as digital signals from SCSI, for example. When a drive 48 such as internal MO or MD is to be used, images and various data are recorded on the recording medium.

The taken pitch-shifted images and color images are transferred to a computer connected to the measuring apparatus, together with various taking lens information. In the computer, based on the transferred pitch-shifted images and the taking lens information, the data are calibrated and converted to a distance image having information with respect to the distance to the object. As for the pitch-shifted image, after calibration, a conversion curve with respect to the stored amount of shifting and measured distance is extracted for every XY position, longitudinal and lateral positions on the image plane, focal length f and in-focus position d, and the pitch-shifted image is converted to a distance image based on the relevant conversion curve.

Conversion to the distance image is well known and the detailed explanation is given, for example, in Institute of Electronics, Information and Communication Engineers, Workshop Material PRU 91-113, Onodera et al., "Geometrical Correction of Image Without Necessitating Camera Positioning", Journal of Institute Electronics, Information and Communication Engineers, D-II vol. J74-D-II, No. 0, pp. 1227-1235, '91/9 Ueshiba, Yoshimi, Oshima et al, "Highly Precise Calibration of a Range Finder Based on Three-Dimensional Model of Optical System."

Hereinafter, the imaging method and the data processing of the present invention will be described in detail.

Firstly, high-precision input by divisional taking, using a camera universal head, in the three-dimensional shape measuring apparatus is described. The three-dimensional resolution and precision are determined when the distance between the light projection system and the light receiving system, i.e., the base length l, focal length f and a distance d to an object to be measured are determined. Thus, the high-precision measurement is achieved by elongating the focal length f. In other words, the precision in measurement increases in teleside. In such a case, however, although a three-dimensional image of high precision in measurement may be obtained, the field of view becomes narrower as the focal length f become longer.

Therefore, the focal length f is set to a value corresponding to the desired resolution and precision for measurement and the range of the field of view is divided into a plurality of regions by operating a rotary frame 4 such as an electrical universal head. Measurement is performed for every divided region, and the resulting images are put together or patched up to re-construct one image. By providing such a function, a three-dimensional shape measuring apparatus of which resolution can be varied is realized. By utilizing this function, environmental measurement becomes possible by performing three-dimensional measurement of the entire peripheral space. This operation will be described referring to a specific example. The example shown in Fig. 8 is a simplified illustration, in which the light projecting system 2 and light receiving system 3 are arranged at positions having horizontal relation, which is different from the example shown in Fig. 3. In this arrangement, the slit shaped light has its length extending in the longitudinal direction, and therefore scanning must be carried out in left and right directions.

The manner of operation utilizing the image patch up function is shown in Fig. 8. Fig. 9 is a flowchart of the operation utilizing the image patch up function. Fig. 10 shows the state of display when this function is used, in which there is provided a display portion indicating the precision

in measurement below the image display portion.

Firstly, referring to Fig. 8 (a), the zoom drive system 16 is driven to set the range of the field of view to a wide angle state (focal length f0), allowing sensing of the object 1 in the range of the field of view, by the operation of the user (step #101). The resolution in the Z axis direction (see Fig. 4: the direction of the ups and downs of the object) assumed at this time is represented by a bar indication below the image, as shown in Fig. 10 (a). When the base length is fixed as in the present system, briefly, the resolution $\Delta Z$ in the direction of the Z axis satisfies the following relation between the distance d to the object to be measured and the focal length f at the time of measurement:

$$\Delta Z = K \times d\,(d - f) / f \qquad \ldots (1)$$

where K is a coefficient for estimating the resolution in the direction of the Z axis, which is determined by the sensor pitch and so on. The zooming operation described above is performed by transmitting a command from a system computer through SCSI terminal. Setting of operations such as zooming operation and releasing operation can be made by remote control.

When the user determines that the above-described setting allows measurement with sufficient precision and sufficient resolution (NO in step #102), then measurement is started by the releasing operation by the user (step #103), and the result is given on the display (step #104). In this display, the input pitch-shifted image or color image is displayed, as well as the measurement resolution in the direction of the Z axis obtained at that time, displayed in the shape of a bar below the image, as shown in Fig. 10 (a). As a result, if measurement with higher precision is not necessary (NO in step #105), measurement is completed, and whether or not the obtained result is to be written to a storage medium is determined, and the corresponding processing is performed. Thus the operation is completed.

When the user determines that measurement is not performed with sufficient precision (YES in step #102), the user can instruct re-measurement with the precision and resolution changed by key operation to the desired resolution in the direction of Z axis and desired precision, referring to the pitch-shifted image taken by the first releasing operation or

referring to the display of the measured resolution in the direction of the Z axis (YES in step #105).

When the key input for setting the precision is entered, the system stores the state at that time. More specifically, the system stores the focal length f0 at which the complete view of the object is obtained, and approximate distance d to the object to be measured obtained from the AF sensor, and hence stores the scope of the field of view (step #106). Further, based on the input desired measurement resolution in the direction of the Z axis and the approximate distance d, the system calculates the focal length f1 to be set in accordance with the equation (1) above (step #107).

When the focal length f1 is calculated, automatic zooming is performed to the focal length f1 (step #108); the number of frames to be input in divided manner and the angles of panning and tilting are calculated based on the stored scope of the field of view to be measured, the approximate distance d, and the focal length f1, and the position of the field of view is set by panning and tilting rotary frame (step #109); and measurement is performed for every divided input frame (step #110). The images input dividedly when the image patch up function is utilized are set to include overlapping portions which are used for patching up the divided images to re-construct the original one image.

The obtained pitch-shifted image, color image, information indicative of the directions of the field of view in the X and Y directions taken (for example, decoded angle values of panning and tilting, order of taking in the X and Y directions, and so on), the lens focal length, and information of measurement distance are stored in an internal MO storage device (step #111). At this time, directory information such as file name, file size and so on may not be written to the memory but such directory information may be written after confirmation by the user at the last step of operation, so that the information is stored temporarily.

Thereafter, by controlling the field of view to a position of the field of view slightly overlapping the position of the field of view of the previous operation by panning and tilting in accordance with the calculated angles of panning and tilting, the image of the adjacent region is input. By

repeating this operation, the images of the entire regions are input (NO in step #112, see Fig. 8 (b)).

Upon completion of the input of the entire region (YES in step #112), the initial camera attitude and initial focal length before enhancing the precision in measurement are resumed (step #113) and the operation is completed. The control waits for the determination of writing by the user. When there is a write instruction, directory information is written. If there is not a write instruction, the directory information is not written and the operation is completed. In that case, the information continuously stored in the memory is erased.

When measurement is performed in advance and thereafter measurement is again performed as in the operation of the above example, the distance to the object and distribution of the distance in the view angle of measurement have been completed by the first measurement. Therefore, re-measurement for patching up is not performed for such a divisional input frame having large difference from the distance to the object, that is, the frame consisting only of the peripheral region (background) different from the object, and re-measurement may be performed only for the divisional input frames including the object to be measured. In the example shown in Fig. 10 (b), the dotted region including the object of measurement corresponds to the region for which re-measurement is performed. Other regions do not include the object for measurement and therefore re-measurement is not performed therefor.

As described above, high-speed three-dimensional measurement is possible, and, by repeating partial inputs and patching up the resulting images based on the three-dimensional measurement, three-dimensional shape measurement can be performed of which resolution can be set freely.

In such a patch up measurement, the resolution of the whole image frames is uniform. However, there may be an object that requires data of high resolution for some portions and low resolution for other portions. For example, eyes, mouth and nose of one's face are abound in complex shape and color information, while low resolution is sufficient for measuring cheeks, forehead and so on. For such an object, patch up of

data may be utilized by partial zooming operation, which results in highly efficient data input. The partial zooming patch up function is realized by the following operations.

Fig. 11 is a flowchart showing the partial zooming patch up function. First, in step #201, setting of the field of view providing the complete view of the object is performed, in the similar manner as the uniform resolution patch up described above. In step #202, partial zooming input mode is selected. When selection is done, presently set values of focal length f0 and values of decoded angles of panning and tilting are stored (step #203). Measurement is started with focal length f0, and image input is provided as rough image data (step #204). The pitch-shifted image, color image, information indicating the directions of the field of view in the X and Y directions at which the image is taken (for example, decoded angle values of panning and tilting), the lens focal length, and information of measurement distance are stored in an inner storage device (step #205). Thereafter, in step #206, zooming is performed to attain the maximum focal length fmax, the rough image data mentioned above is analyzed, and whether or not re-measurement is to be performed on every divided input frames input after zooming is determined.

When zooming is performed and measurement is done with the maximum focal length fmax, the approximate data is divided to the frame size to be input. In step #207, the positions X, Y for panning and tilting are set to the start initial positions Xs and Ys. In step #208, panning and tilting are controlled to the positions X and Y. Then, in step #209, color information, i.e., R, G and B values of the initial input color image of the region $X \pm \Delta X$ and $Y \pm \Delta Y$ are subjected to statistical processing, and standard deviations $\sigma R$, $\sigma G$ and $\sigma B$ of respective regions are calculated. In step #210, whether all the calculated values of the standard deviations $\sigma R$, $\sigma G$ and $\sigma B$ are within the set previous values are determined. If these are within the prescribed values, it is determined that the small area has uniform brightness information, and therefore zooming measurement is not performed but the flow proceeds to step #211. When any of the standard deviations $\sigma R$, $\sigma G$ and $\sigma B$ exceeds the prescribed value, it is determined

that the small region has complicated color information, and therefore zooming measurement is performed (step #213).

In step #211, standard deviation σd is calculated based on the information of the initial input distance value d in the region of X ± ΔX, Y ± ΔY. In step #212, whether the calculated value of the standard deviation σd is within a set prescribed value is determined. If it is within the prescribed value, it is determined that the small region is a flat region having little variation in shape, and therefore zooming measurement is not performed but the flow proceeds to step #215. If it exceeds the prescribed value, it is determined that the small region has complicated shape (distance information), and zooming measurement is performed (step #213).

After the zooming measurement in step #213, the obtained pitch-shifted image, color image, information indicative of the direction of the field of view of Z and Y directions at which the image is taken (for example, decoded angle values of panning and tilting), lens focal length, information of distance for measurement and so on are stored in an internal storage device such as MO (step #214). Thereafter, the flow proceeds to step #215.

In step #215, the panning and tilting position X is changed by 2 X. In step #216, whether or not scanning in the X direction is completed is determined. If it is not completed, the flow returns to the step #208. If it is completed, the panning tilting position Y is changed by 2 Y in step #217. In step #218, whether scanning is completed or not is determined, and if it is not completed, the flow returns to step #208. If the scanning is completed, the flow proceeds to step #219, and this routine terminates.

In this manner, both the schematic image data and partial detailed image information allowing determination of the position can be input. By patching up the data of the schematic image and the partial detailed image data corresponding to the position, highly efficient three-dimensional input corresponding to complexities of the shape and color information can be realized.

In the above-described embodiment, photographing is performed with precision corresponding to the shape and color of the object by changing the focal length of the lens by zooming. However, it is also

possible to use two lenses (lenses of long focal length and short focal length), i.e., to use the lens of long focal length for a region where the shape and color of the object are determined to be complex and the lens of short focal length for the other region.

The data processing for patch up is now described.

In this processing, data of a plurality of images input by the above-described camera device are coordinate converted into one coordinate system to thereby obtain data of one image.

Firstly, the case where patch up is performed with a camera mounted on a universal head is described. In this case, a plurality of pictures of a fixed object are taken by panning and tilting the camera mounted on the universal head that allows panning and tilting, and the data of the plurality of photographed images are converted to one coordinate system to obtain a patched up image.

As described in the "Problems to be Solved by the Invention" above, when the camera is to be panned and tilted, highly precise patching up is possible without any problem if the angle of rotation can be controlled precisely. However, such a highly precise universal head is very expensive, and therefore photographing by using a general, not so expensive universal head is desired, which universal head may have considerable error in controlling the angle of rotation.

In that case, a camera model such as shown in Fig. 12 is prepared. This is a camera which allows panning and tilting, represented in a three-dimensional coordinate system. In Fig. 12, the reference character C denotes the camera, $\Theta$ denotes the axis of rotation of the camera (panning), and $\Phi$ represents the axis of rotation of the camera (tilting).

Parameters of the model (position and direction of the axis of rotation for panning, position and direction of the axis of rotation for tilting) are calculated in advance by calibration. Searching of the junction point (at which two image data are jointed) carried out subsequently is performed by changing parameters $\Theta$ (pan angle) and $\Phi$ (tilting angle) of the model.

This operation is now described with reference to the flowchart of Fig.

13. Firstly, two-dimensional color image, three-dimensional data, focal length and the distance to the reference plane are taken from the photographed data (stored in the storage device in the camera apparatus, as described above) (step #301). Then, the junction point is searched for from the two-dimensional color image (step #302: details will be given later).

However, the points of measurement of the two images photographed by panning and tilting the camera do not always coincide with each other (even when the images are photographed with the same sensing distance and focal length, the images deviate from each other by half pixel, at most). Therefore, when the deviation is within 1 pixel, searching of the junction point is regarded successful, based on the color image (two-dimensional data), and searching hereafter is performed by using the three-dimensional data.

Firstly, based on the junction point of the two-dimensional images, the focal length and the distance to the reference plane, the angles of camera rotation (pan angle $\Theta$ and tilting angle $\Phi$) are calculated (step #303, details will be given later). Thereafter, according to the calculated camera rotation angles, coordinate conversion parameters for the three-dimensional space are calculated (step #304, details will be given later).

Then, a square sum of an angle formed by normals of two planes passing through the junction portion is regarded as an evaluation value, and search for minimizing the evaluation value is performed (step #305). The method of calculating the evaluation value will be described in detail later.

Since rough search is performed using the two-dimensional images, search in a very narrow scope is enough for the three-dimensional data. Therefore, the amount of calculation in total can be reduced as compared with the search utilizing the three-dimensional data only, whereby patch up operation can be done at high speed.

Thereafter, whether the calculated evaluation value is within a prescribed value is determined (step #306). When it is not larger than the prescribed value, two three-dimensional images are converted to the same coordinate system by using the last calculated coordinate conversion

parameter for patching up (step #307) and the operation is completed (step #310). The method of coordinate conversion will be described later.

When the evaluation value is larger than the prescribed value in step #306, then whether the number of repetition of continuity evaluation is not smaller than a prescribed number is determined (step #308). If it is not smaller than the number, the patch up operation in step #307 is performed. The reason is that when the number of repetition exceeds a prescribed number, the evaluation value converges, making further repetition unnecessary.

When the number of repetition is smaller than the prescribed number in step #308, then the angle of rotation of the camera is slightly changed so that the evaluation value calculated in step #305 becomes smaller (step #309). Thereafter, the flow proceeds to step #304 and continuity evaluation of the patches at the junction portion is repeated.

In the following, each of the steps will be described in greater detail.

Firstly, the searching method of the junction point from two-dimensional color images in step #302 is described with reference to Figs. 14-16. The description is given on the premise that two images to be patched up have overlapping portions (having the width of T pixels) as shown in Fig. 14. Referring to Fig. 15 (a), a reference window is set at a central portion of the overlapping portion of one of the images (the dotted line in Fig. 15 (a) denotes the center line of the overlapping portion). Fig. 15 (b) is an enlarged view of the reference window portion of Fig. 15 (a). This reference window is further divided into small windows each having the size of about $8 \times 8$ (pixels). Of the small windows, one having a complicated shape or complicated patterns (having large value of distribution) is used as a comparing window. The reason for this is that when a portion having clear edges or complicated patterns or shapes is used, reliability of evaluation can be improved.

On the other image, a searching window which has the same size as the reference window and which is movable to move on the entire overlapping portion is set (Fig. 16).

In this searching window, small windows are provided at relatively

the same positions as the comparing windows in the reference window. The square sum of the difference in luminance between the small window and the comparing window is used as the evaluation value, and the junction point is searched.

Next, the method for calculating a camera rotation angle based on the two-dimensional image junction point, the focal length and the distance to the reference plane of step #303 is described.

When we represent the pixel size as PS, camera plane size as $2 \times S$, focal length as f, and the number of shifted pixels as T, the camera rotation angle θ can be obtained by the following equation, if the axes of rotation and the camera position coincide with each other (that is, the rotation axis intersects the optical axis of the camera) (Fig. 17):

$$\theta = \pi - \arctan (S / f) - \arctan ((S - PS \times t) / f)$$

If the rotation axis does not coincide with the camera position (when the rotation axis and the camera axis are deviated from each other), the following relation holds, where r represents radius of rotation (distance between the rotation axis and the optical axis of the camera), and D represents the distance to the reference plane:

$$t \times PS \times D/f = 2S \times D/f - (D + r \times \sin \theta) / \tan(\pi - \arctan (f/S) - \theta) - S \times D/f - r \times \cos \theta$$

When the rotation axis and the camera position do not coincide with each other, the calculation becomes very complicated and the angle of rotation cannot be obtained easily. Therefore, it is preferable to provide a table showing the number of pixels (t) and the corresponding angles obtained by searching, so that the angle of rotation can readily be found.

The method for calculating the coordinate conversion parameter of the camera in step #304, and the method of coordinate conversion of step #307 are now described. When we represent the coordinate systems of two cameras as C1 (X1, Y1, Z1) and C2 (X2, Y2, Z2), the position of the camera rotation axis as T (t1, t2, t3) and the direction of rotation of the camera as (1, 0, 0) (rotation about the X axis in the coordinate system of C1), then C2 when rotated by θ about the axis of rotation is converted to the coordinate system of C1 in accordance with the following equation:

$C2 - T = R(\theta) \bullet (C1 - T)$

where R (θ) is obtained by the following equation, based on the angle θ of camera rotation:

$$R(\theta) = \begin{vmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{vmatrix}$$

Therefore, conversion of the C2 coordinate system to the C1 coordinate system can be represented by the following equation, using parameters R (θ) and T:

$C1 = R(\theta)^{-1} \bullet (C2 - T) + T$

More specifically, the point C1 (of C1 coordinate system) is moved in parallel onto the rotation axis, the coordinate is converted to the C2 coordinate system on the rotation axis (rotated by θ), and the point is moved in parallel from the rotation axis to the point C2.

The above-described operation is for the panning angle. Similar coordinate conversion can be performed by using the Y axis as the rotation axis for the tilting angle.

The method for calculating the continuity evaluation value of the patches at the junction portion in step #305 is now described in greater detail with reference to the flowchart of Fig. 18 and to Fig. 19.

Firstly, three-dimensional data of two images including the point of junction searched for from the two-dimensional color images are taken (step #401). Thereafter, normals at the center of the planes 1-12 at the portion of junction between the first image (the image represented by the white circle in Fig. 19) and the second image (the image represented by the block circle in Fig. 19) are calculated (step #402).

Then, for the first image,

e1(1) = (angle formed by the normals of 1 and 2–1) – (angle formed by the normals of 1 and 2–12)

is calculated. Similar calculation is performed for n sets of planes following the plane 4, and square sum (E1) of the results is obtained (step

#403).

For the second image,

e2 (1) = (angle formed by the normals of 3 and 2–2) – (angle formed by the normals of 3 and 2–12)

is calculated. Similar calculation is performed for n sets of planes following the plane 6, and the square sum (E2) of the results is obtained (step #404).

Then, whether a smooth junction is obtained or not is evaluated by using

$(E1 + E2) / n$

(step #405), and the evaluation value is returned to the main routine (step #406).

Patch up of the data photographed by a plurality of cameras is now described. When a plurality of cameras are used for photographing, the relative position and orientation can be measured by sensing the cameras by each other. Therefore, based on the data, the position of the object (corresponding to the position of the rotation axis) and the angle between the cameras viewed from the object (corresponding to the angle of rotation) are calculated. Based on these calculated values, coordinate conversion parameters are calculated, and two three-dimensional images are converted to the same coordinate system and patched up. The details of the patching up operation are similar to those when the camera frame is used described above. Therefore, description thereof is not repeated here.

When the cameras are photographed by each other, the camera position can be calculated with higher precision if a lens having longer focal length than used for sensing the object is used. By doing so, undesirable influence on the object data at the time of patching can be avoided.

Next, patch up of data when the object is photographed placed on a rotary stage is described with reference to Fig. 20 and the flowchart of Fig. 21. Fig. 20 shows the rotary stage on which the object is placed. The rotary stage has polygonal circumference. The normal of each plane is orthogonal to the rotation axis, and the planes are arranged at equal distance from the rotary axis. Therefore, when each plane is measured,

the distance and position of the rotary axis of the rotary stage can be calculated.

For example, four three-dimensional and two-dimensional data are photographed (step #502) by rotating the rotary stage by 90 degrees for every sensing operation, such that the rotary stage is within the measurement scope as shown in Fig. 22 (which is a model of sensing operation using the rotary stage). Thereafter, with respect to the data of the photographed four images, the data of the object and the data of the rotary stage portion are separated from each other, and a group of planes, which is lower part of the rotary stage, is extracted (step #503). At this time, the plane portion of the rotary stage may have a specific color, to further facilitate extraction with the color image.

Thereafter, using the data of the rotary stage portion from among the data separated in step #503, the position and attitude of the rotary stage are calculated (step #504). This method will be described in greater detail later.

Based on the position and attitude of the rotary stage and the angle of rotation calculated in the subroutine of step #504, coordinate conversion parameter (about the rotation axis) for each photographed data is calculated (step #505). Based on the parameter, coordinate conversion is performed, whereby respective photographed data are integrated in one coordinate system (step #506). The method of calculating the parameter from the rotation angle and the method of coordinate conversion are the same as the method of calculating the parameter and method of coordinate conversion when the above-described camera universal head is used, except that the angle of rotation of the camera is replaced by the angle of rotation of the rotary stage.

Thereafter, the junction portion is set (the method will be described later), data out of the scope of each photographed data is deleted, a plane is re-constructed at the junction portion (step #507), and patching up of the three-dimensional data is completed (step #508).

As a result, as shown in Fig. 23, the first image (represented by the black points) and the second image (white points) are patched up at the

boundary, thus resulting in one image.

The method for calculating the position and the attitude of the rotary stage in step #504 is now described with reference to the flowchart of Fig. 24. Firstly, three-dimensional data of the rotary stage and the color image of the rotary stage are taken (step #601). The data is divided for each plane (step #602). Thereafter, normal vector of the plane is calculated for every plane (step #603). A line that is orthogonal to the normal vector and at an equal distance from respective plane is defined as the rotation axis (step #604), and the rotation axis is returned to the main routine as the position and attitude of the rotary stage (step #605).

The method for setting the junction portion is now described in greater detail.

Firstly, the case where the real data photographed is not changed is described with reference to the flowchart of Fig. 25. Firstly, of the data cut at the boundary of the images (four planes including the axis of the rotary stage and orthogonal to each other), only that data which is sandwiched by two boundaries of images is regarded as effective data, and other data are canceled (step #701). Correspondence between end points of the photographed data is determined (two points which are close to each other are regarded as corresponding points), the images are patched up successively (step #702), and the flow returns to the main routine (step #703).

In this case, when the data are canceled, overlapping portions may be left for two images to be patched up. By doing so, patching up can be performed smoothly by searching for the junction point, as already described with reference to the patching up operation using a universal head for the camera.

The case where photographed data are changed for smooth patch up operation is now described with reference to the flowchart of Fig. 26 and to Fig. 27. With respect to photographed data, points approximately at the same distance from the boundary between the images (four planes including the axis of the rotary stage and orthogonal to each other) are determined as corresponding points (1–1 and 2–1, 1–2 and 2–2, ..., 1–n and

2–n of Fig. 27) (step #801), and a new point (the point marked by × in Fig. 27) is generated based on two points corresponding to the data up to a prescribed distance from the boundary (step #802). The new point that is to be generated is determined in the following manner, in accordance with the distance from the boundary.

When we represent a prescribed scope (in which the new point is generated) from the boundary as D, the point of one photographed data as X1, the point of another photographed data as X2, average distance from the boundary to the two points (X1, X2) as d, and the newly generated point as X3, then the following relation holds:

$$X3 = ((D+d) \times X1 + (D-d) \times X2) / (2 \times D)$$

The plane is re-constructed by using the newly generated data near the boundary (the scope whose distance from the boundary is up to D) and by using real data at other portions (the scope whose distance from the boundary exceeds D) (step #803), and the flow returns to the main routine (step #804).

Further, by applying a recess/projection at every 90 degrees on the rotary stage as shown in Fig. 20 (b), the angle of rotation can be made very precise at extremely low cost. By performing coordinate conversion based on the axis of rotation calculated in advance for the four images photographed with the stage rotated, the entire peripheral data can be obtained. When such a rotary stage is used, the object can be set at an arbitrary position within the scope of measurement, and therefore the sensing operation is much facilitated.

The zoom patch up method when a zooming input is provided as described above is now explained with reference to the flowchart of Fig. 28.

Firstly, photographed data having different magnifications are taken in accordance with the method described above in conjunction with the zooming input (step #901). Then, patch up of the images using the camera universal head is performed in the same manner as shown in the flowchart of Fig. 13 described above (except for the last patch up operation), and calculation of the parameter for coordinate conversion and extraction of data at the boundary portion are performed (step #902). Here, before

searching for the junction point from two-dimensional color images (step #302 of Fig. 13), re-sampling is performed for the two-dimensional images and for the three-dimensional images (the method will be described later).

Thereafter, coordinate conversion is performed with respect to the data having high magnification, the data having high magnification is integrated to the coordinate system of data having low magnification (step #903), a plane is re-constructed at the boundary portion (step #904), and the patch up operation is completed (step #905).

Fig. 29 is a model of the zoom patch up operation. Firstly, data (having magnification of N2) of Fig. 29 (b) is re-sampled so that it comes to have the magnification of N1 as shown in Fig. 29 (c), and then re-sampled data is patched up with the data (having the magnification of N1) of Fig. 29 (a). Thereafter, the portion having had the magnification of N2 is returned to have the original magnification (N2), and as a result, a patched up image such as shown in Fig. 29 (d) is obtained.

The re-sampling method of the two-dimensional and three-dimensional images is now described in greater detail.

Firstly, the method for the two-dimensional image is described with reference to Fig. 30.

In Fig. 30, the image represented by the solid lines is the image having the magnification of N1, while the image represented by the dotted lines is the image having the magnification of N2 (in both images, the minimum square corresponds to one pixel, where $N1 < N2$).

Re-sampling is performed for the image having the magnification of N2. The phase is matched so that the pixel at the upper left end of the image having the magnification N2 coincides with a sampling point of the image having the magnification of N1.

The re-sampling value (average brightness) is calculated by using a weighted mean value of the area of the pixels of the image having magnification of N2 included in the pixels of the image having the magnification of N1. More specifically, the product of the brightness and area of the image having the magnification of N2 included in 1 pixel of the image having the magnification N1 are all added, and the result is divided

by the area of one pixel of the image having the magnification of N1.

The operation for the three-dimensional image is now described with reference to Fig. 31. Fig. 31 is a representation viewed from the camera.

In Fig. 31, the image represented by the solid lines and the white circles is the image having the magnification of N1, while the image represented by the dotted lines and the black circles is the image having the magnification of N2 (in both images, the minimum square represents 1 pixel, N1 < N2).

Re-sampling is performed on the image having the magnification of N2. The phase is matched such that the pixel at the upper left end of the image having the magnification of N2 coincides with a sampling point of the image having the magnification of N1.

The re-sampling value is calculated by using an intersection between the line of sight of the camera passing through the point of the image having the magnification of N1, and a two-dimensional curved plane consisting of four points of the image having the magnification of N2 surrounding the relevant point.

In the above-described embodiment, calculation of the parameters for coordinate conversion is performed using both the two-dimensional color image and three-dimensional data. However, the coordinate conversion parameters can be calculated by using only the three-dimensional data, without searching for the junction point from the two-dimensional color image. Though a three-dimensional input has been described in the present embodiment, this invention can be similarly applied to the two-dimensional image input.

[Effects of the Invention]

As described above, according to the image input camera of the present invention, data of a plurality of continuous images are input, and relative positions of the input images are calculated to perform patch up thereof. Accordingly, even in a rough input environment (using a hand-held camera, for example), it is possible to obtain an image that has only a small error in patch up and thus has almost no awkward appearance at the patched up portion.

[Brief Description of the Drawings]

Fig. 1 illustrates the principle of the light-section method.

Fig. 2 is a schematic block diagram of the entire apparatus in accordance with the present invention.

Fig. 3 is a perspective view showing a schematic structure of the entire apparatus in accordance with the present invention.

Fig. 4 illustrates the incident range and the scan range of the reflected light entering the photographing device.

Fig. 5 illustrates the light intensity distribution generated at the plane of the object.

Fig. 6 illustrates the light intensity distribution generated at the light receiving plane of the photographing device.

Fig. 7 illustrates the light intensity distribution generated at the light receiving plane of the photographing device.

Fig. 8 illustrates the image patch up function.

Fig. 9 is a flowchart illustrating an operation of the image patch up function.

Fig. 10 illustrates a display for the image patch up function.

Fig. 11 is a flowchart illustrating an operation of the partial zooming patch up function.

Fig. 12 illustrates a camera model when photographing is performed using a camera universal head.

Fig. 13 is a flowchart illustrating an operation for patching up three-dimensional data photographed by using the camera universal head.

Fig. 14 illustrates the overlapping portions for patching up two-dimensional images.

Fig. 15 illustrates a reference window for patching up two-dimensional images.

Fig. 16 illustrates a search window for patching up two-dimensional images.

Fig. 17 illustrates a calculation method of a camera rotation angle.

Fig. 18 is a flowchart illustrating an operation of continuity evaluation of patches at the junction portion.

Fig. 19 illustrates patch up of data photographed by using the camera universal head.

Fig. 20 is a perspective view showing an appearance of a rotary stage.

Fig. 21 is a flowchart illustrating an operation for patching up three-dimensional data photographed by using the rotary stage.

Fig. 22 illustrates photographing and image patch up operations using the rotary stage.

Fig. 23 illustrates patch up of the data photographed by using the rotary stage.

Fig. 24 is a flowchart illustrating an operation for calculating position and attitude of the rotary stage.

Fig. 25 is a flowchart illustrating an operation of the setting method of the junction portion (without changing the real data).

Fig. 26 is a flowchart illustrating an operation of the setting method of the junction portion (by changing the real data).

Fig. 27 illustrates data generation points in the setting method of the junction portion (with the change of the real data).

Fig. 28 is a flowchart illustrating an operation for patching up three-dimensional data photographed with zooming, using the camera universal head.

Fig. 29 illustrates patch up of data photographed with zooming.

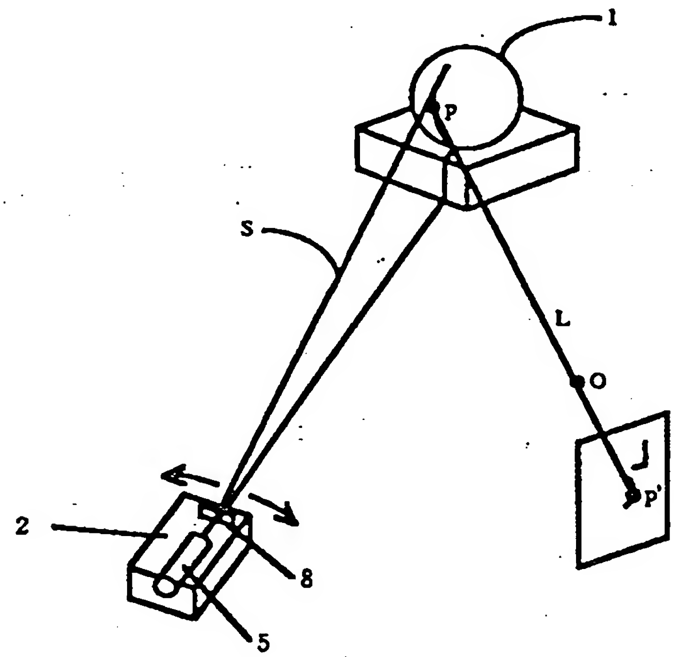
Fig. 30 illustrates re-sampling of two-dimensional images.

Fig. 31 illustrates re-sampling of three-dimensional images.

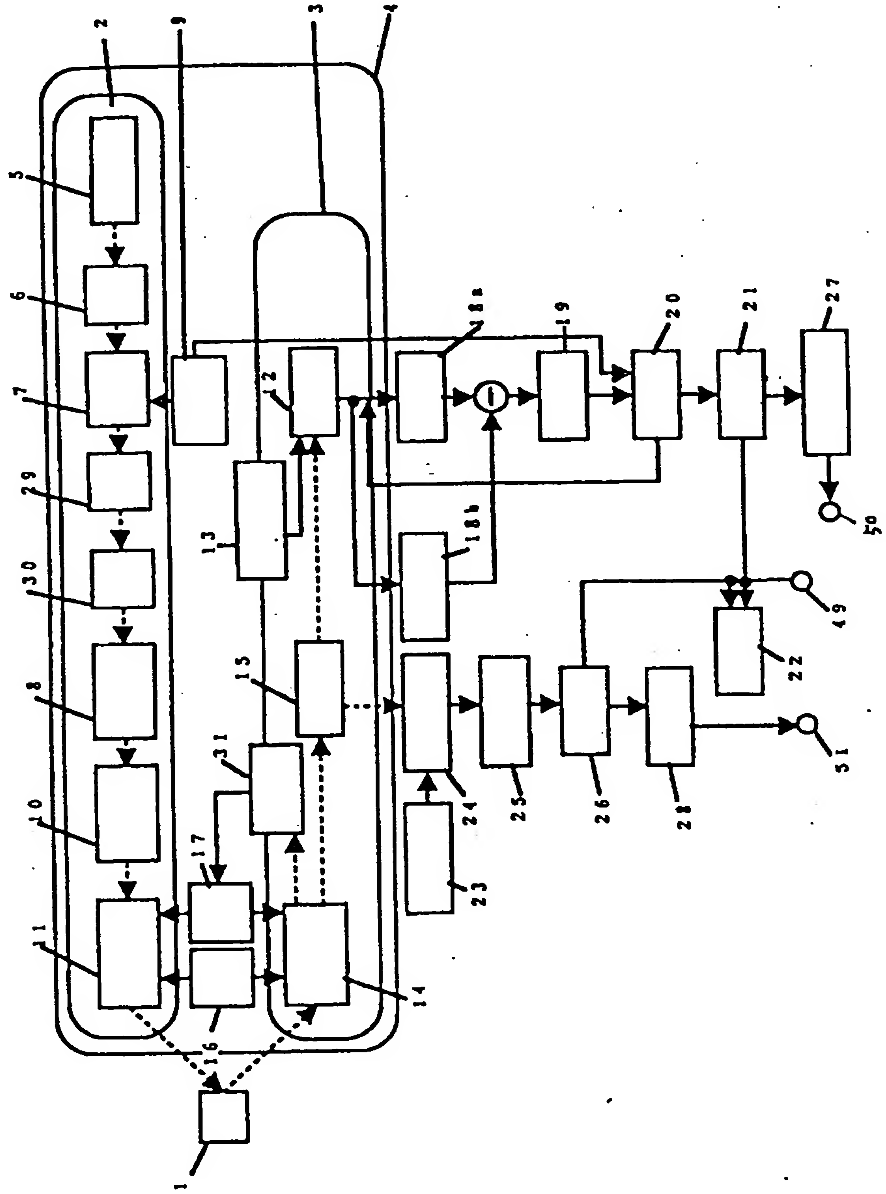
[Description of the Reference Characters]

#301: input means; #502: input means; #304: calculating means; #505: calculating means; #307: patch up means; and #506: patch up means.

【書類名】　図面 drawings
name of document
【図１】
Fig. 1

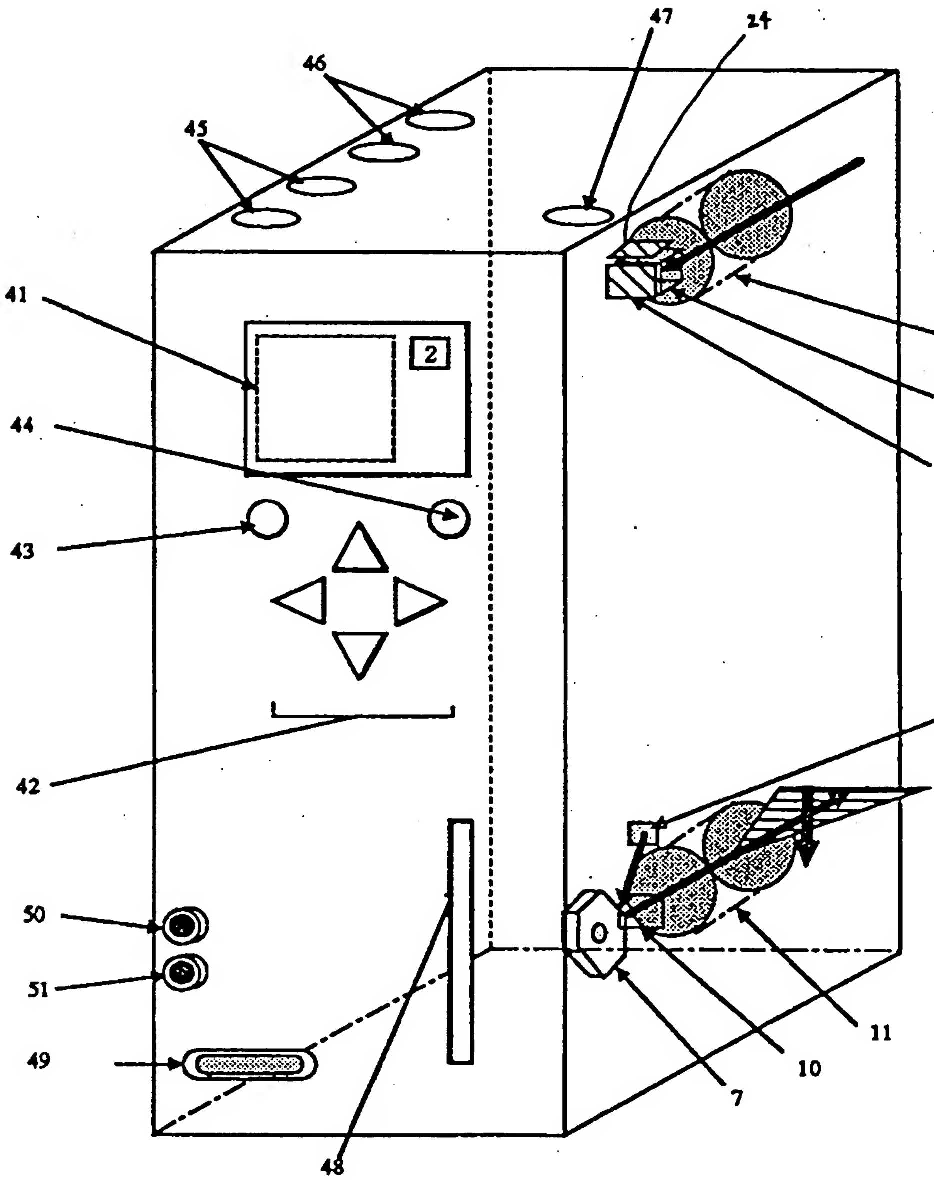


【図２】
Fig. 2

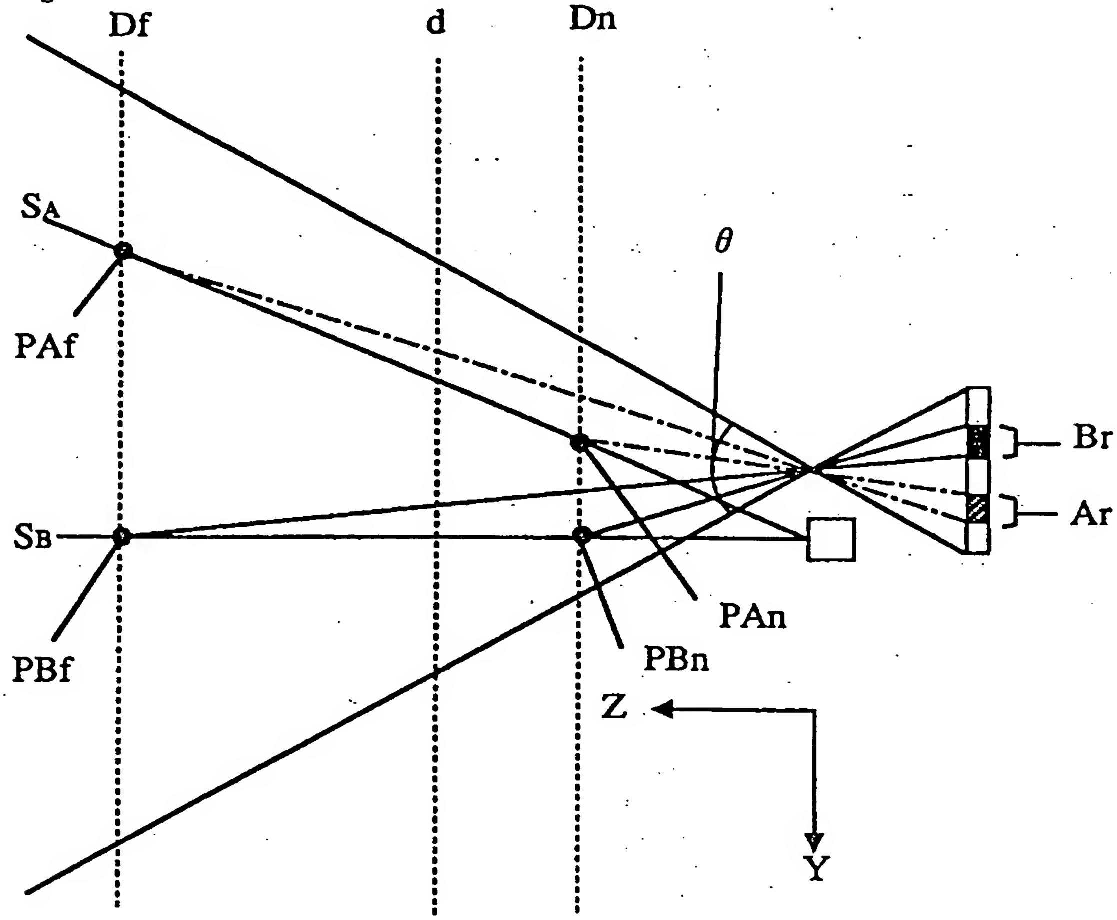

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18a
18b
19
20
21
22
23
24
25
26
27
28
29
30
31
49
50
51

【図３】

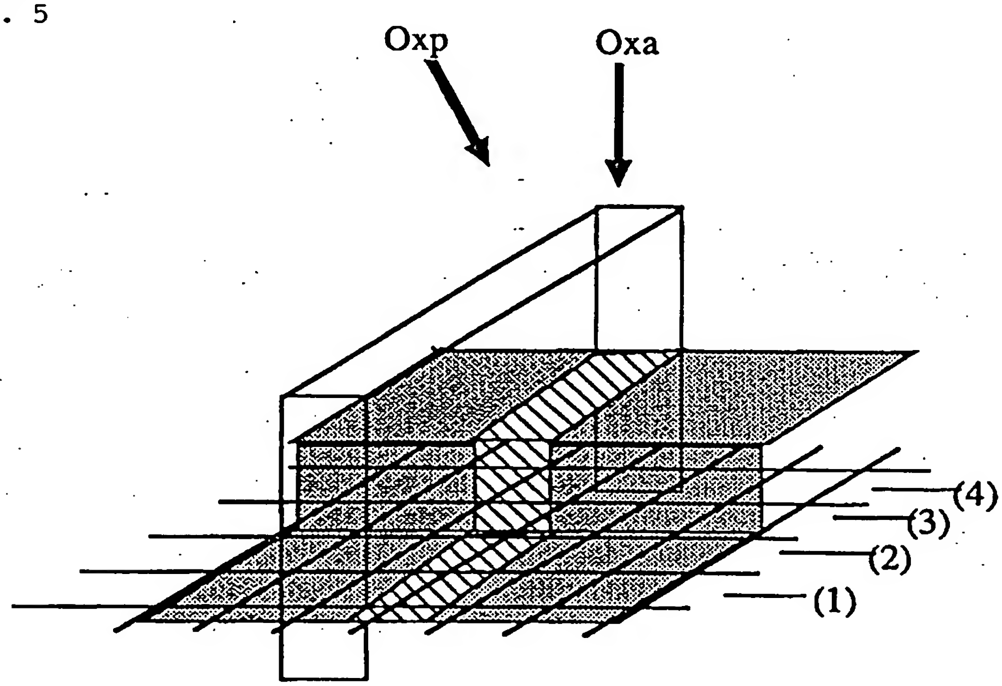
Fig. 3



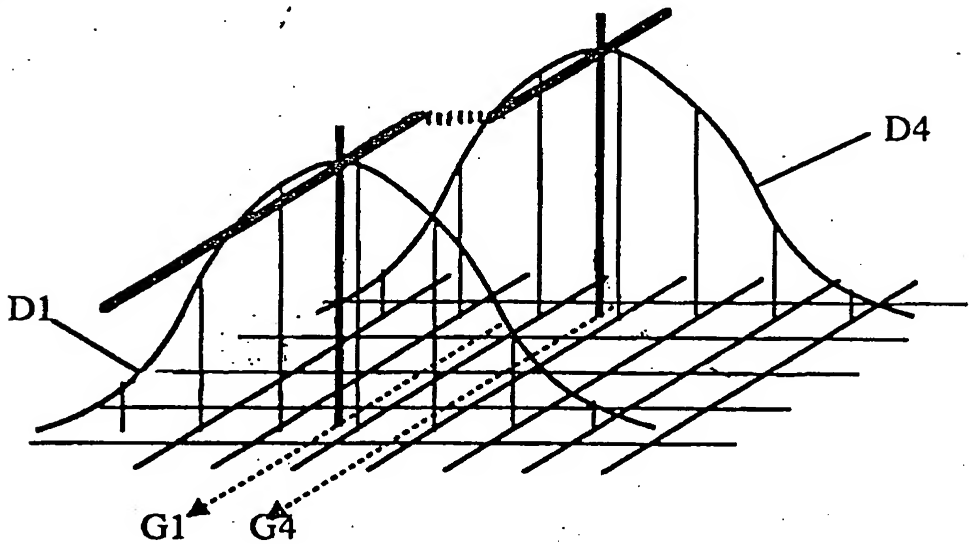
【図４】
Fig.4



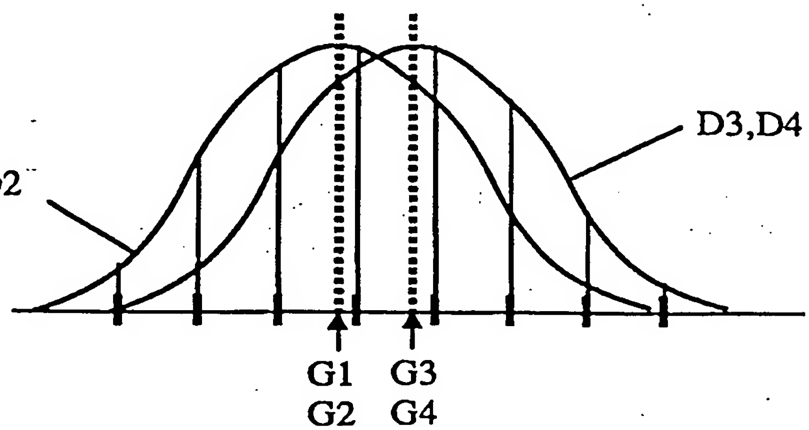
【図５】
Fig. 5



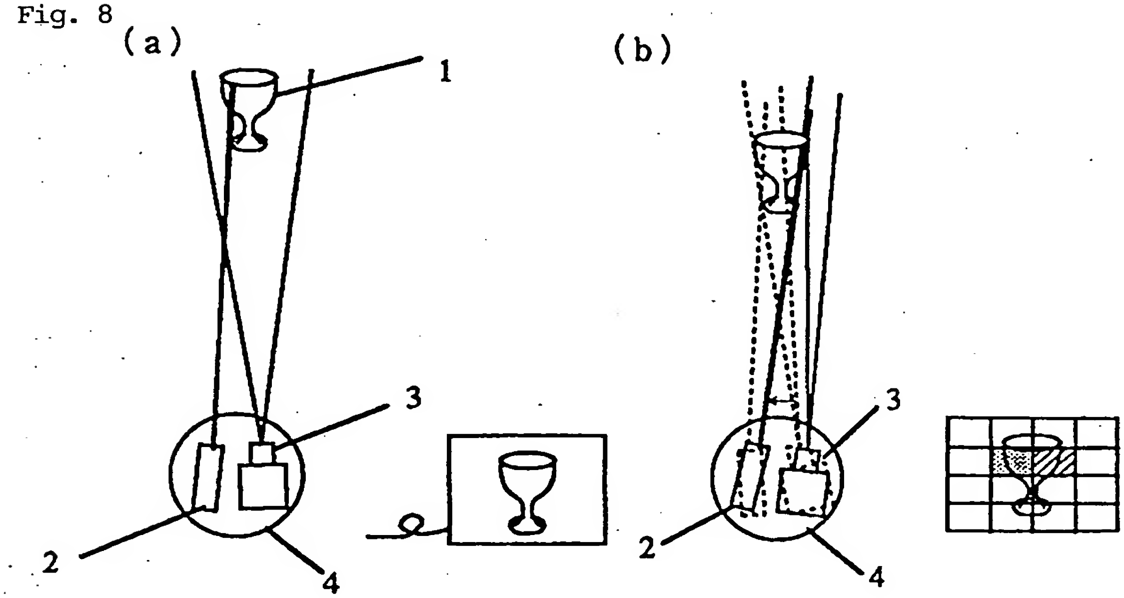

【図６】
Fig. 6



【図７】
Fig. 7

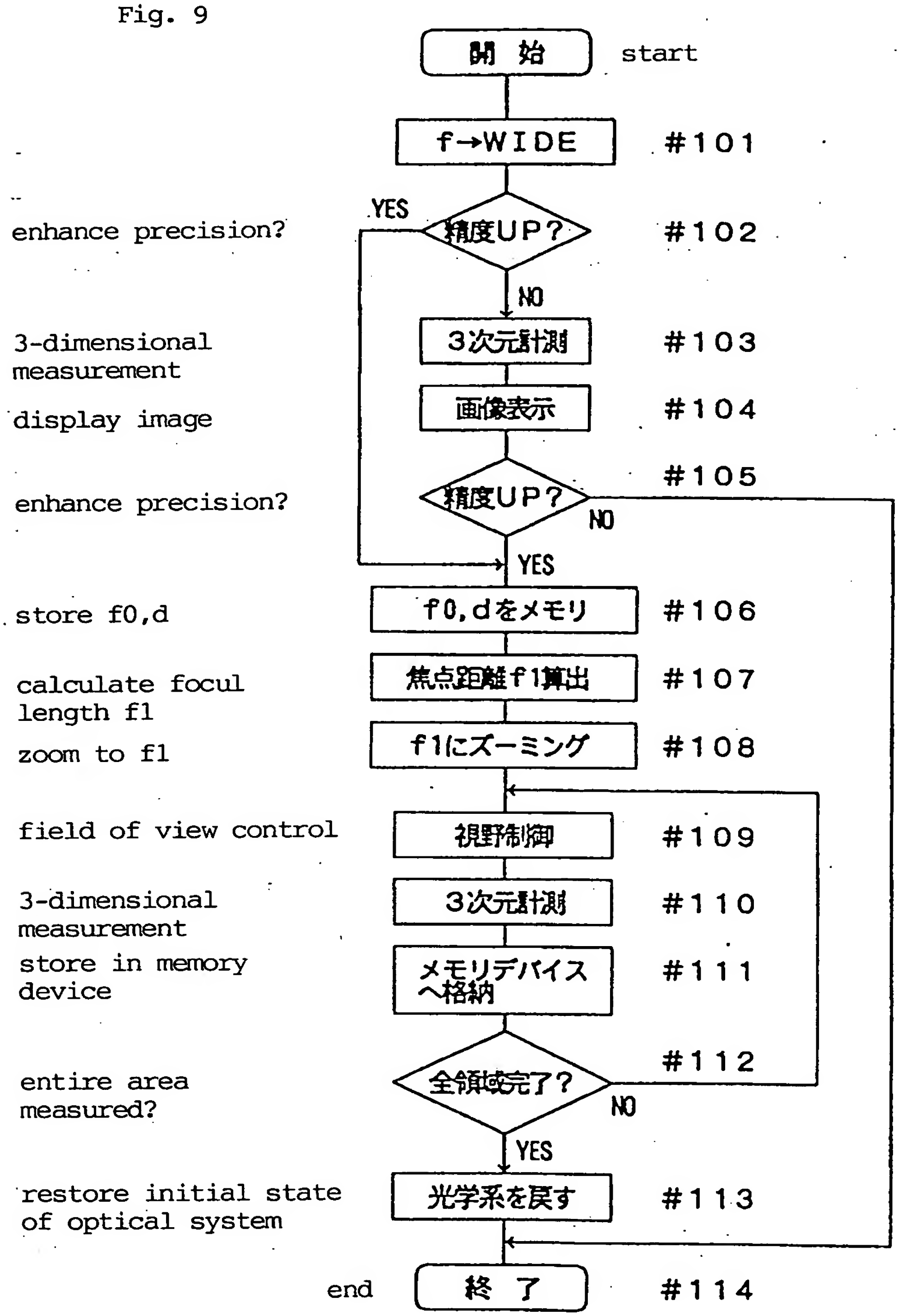



【図８】
Fig. 8

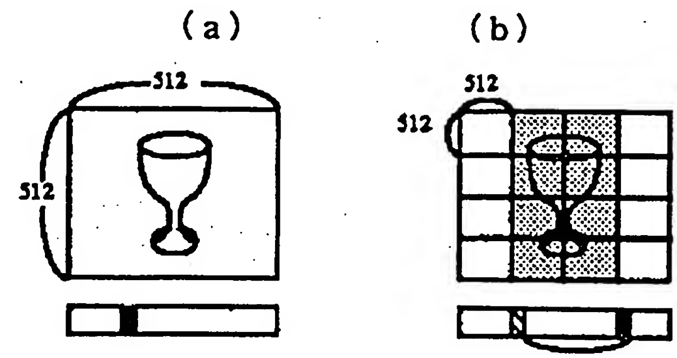


【図9】

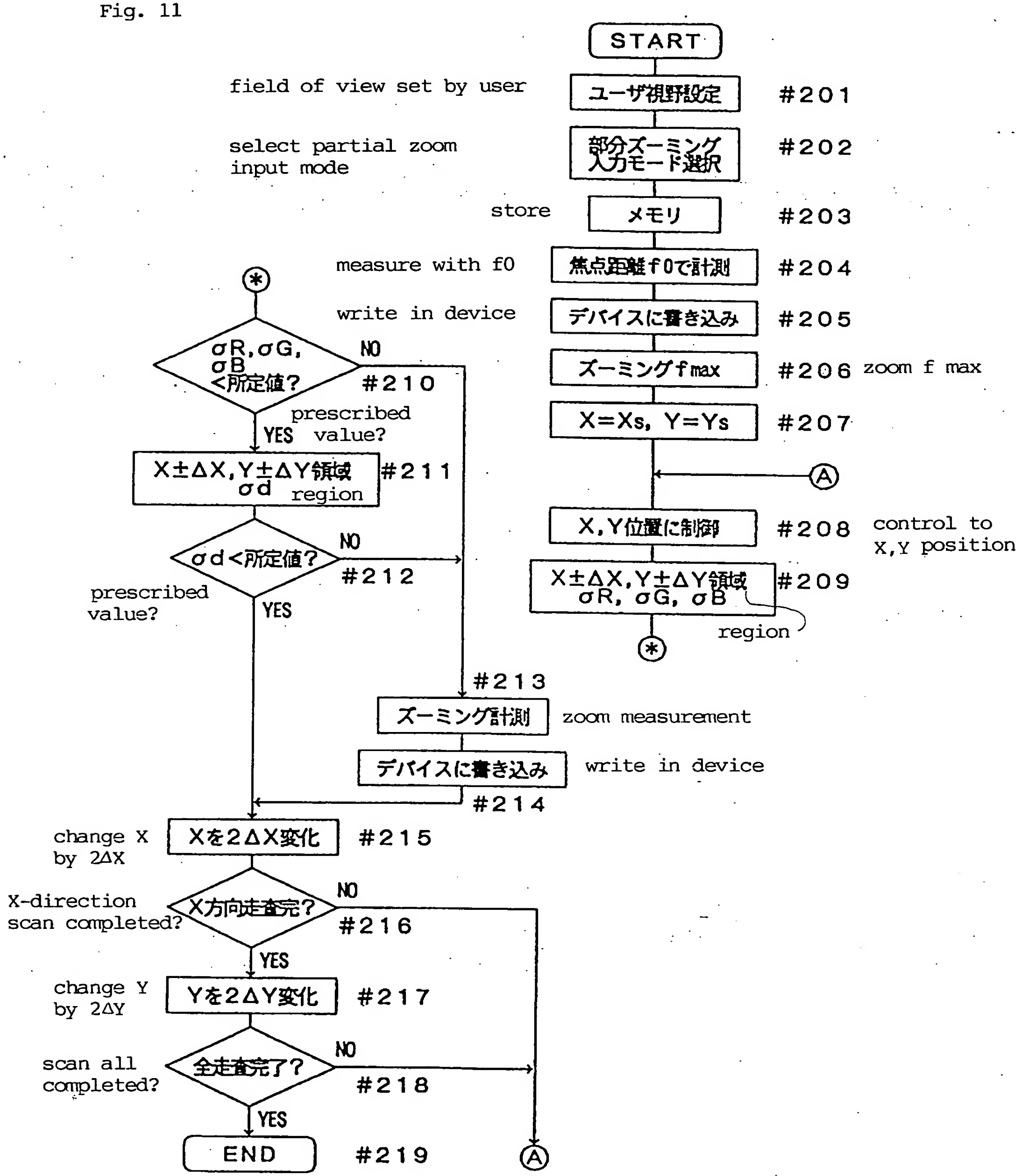
Fig. 9


開 始
start
f→WIDE
#101
YES
精度UP?
enhance precision?
#102
NO
3次元計測
3-dimensional measurement
#103
画像表示
display image
#104
精度UP?
enhance precision?
#105
NO
YES
f0,dをメモリ
store f0,d
#106
焦点距離f1算出
calculate focul length f1
#107
f1にズーミング
zoom to f1
#108
視野制御
field of view control
#109
3次元計測
3-dimensional measurement
#110
メモリデバイスへ格納
store in memory device
#111
全領域完了?
entire area measured?
#112
NO
YES
光学系を戻す
restore initial state of optical system
#113
終 了
end
#114

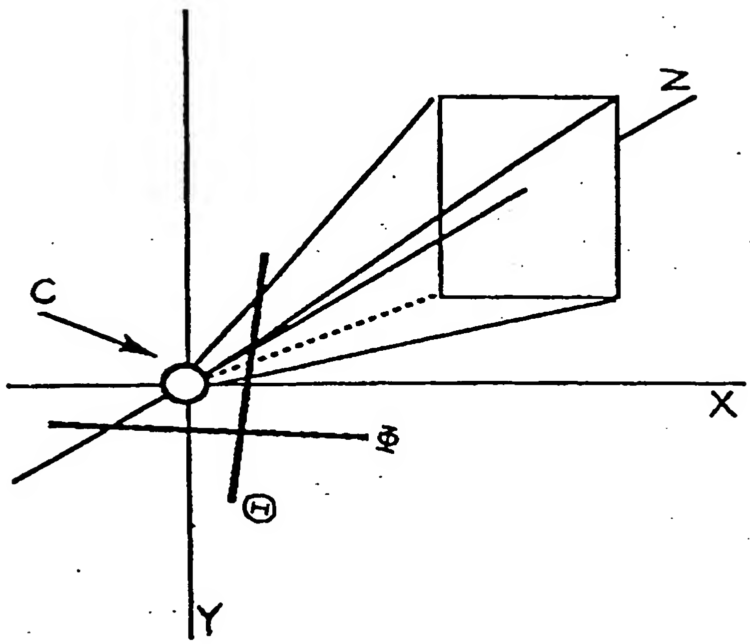
【図１０】
Fig. 10



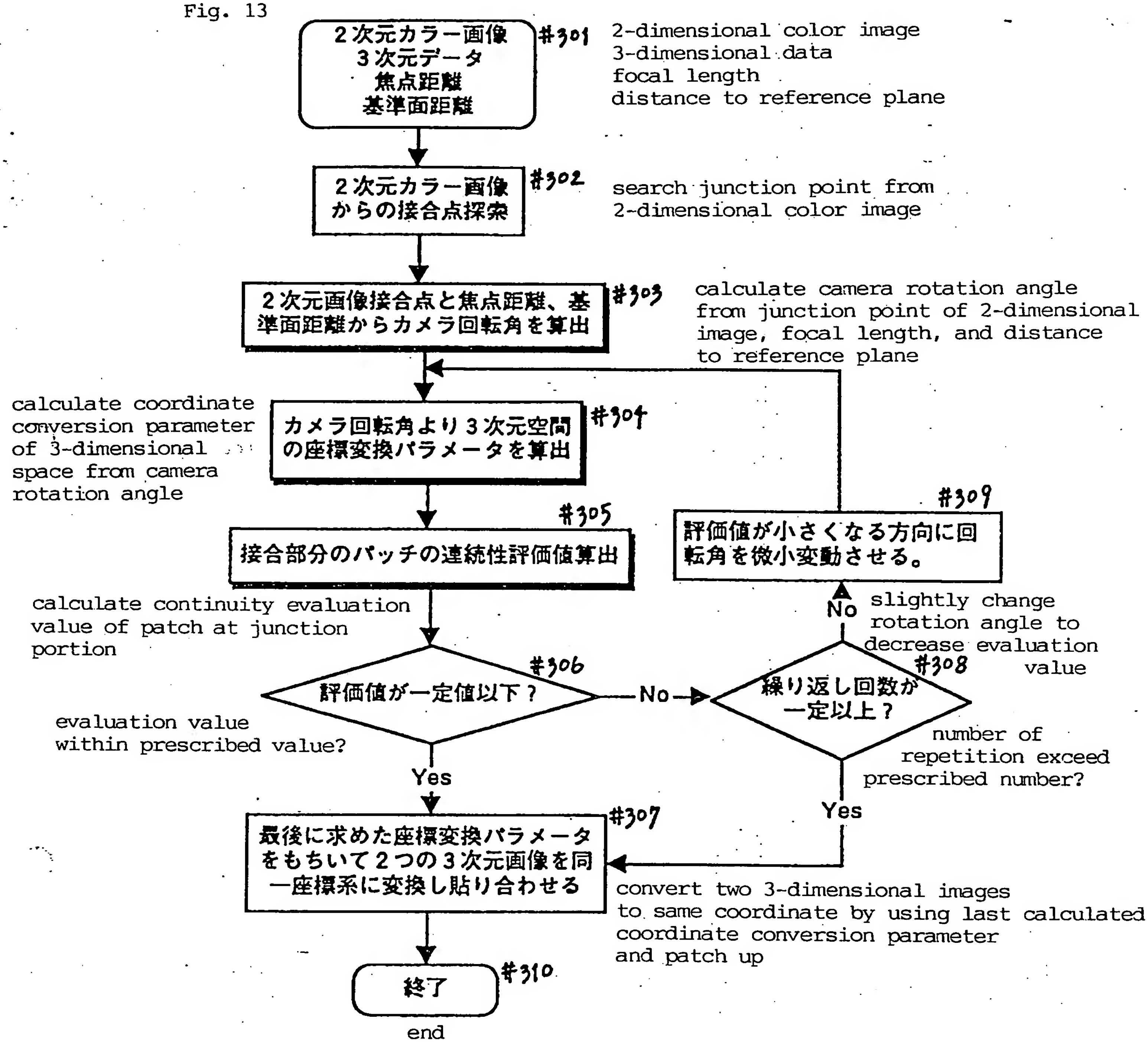
【図１１】
Fig. 11


START
ユーザ視野設定
#201
field of view set by user
部分ズーミング入力モード選択
#202
select partial zoom input mode
メモリ
#203
store
焦点距離f0で計測
#204
measure with f0
デバイスに書き込み
#205
write in device
ズーミングfmax
#206
zoom f max
X=Xs, Y=Ys
#207
A
X,Y位置に制御
#208
control to X,Y position
X±ΔX,Y±ΔY領域 σR, σG, σB
#209
region
σR,σG,σB<所定値?
#210
prescribed value?
NO
YES
X±ΔX,Y±ΔY領域 σd
region
#211
σd<所定値?
#212
prescribed value?
NO
YES
#213
ズーミング計測
zoom measurement
デバイスに書き込み
write in device
#214
Xを2ΔX変化
#215
change X by 2ΔX
X方向走査完?
#216
X-direction scan completed?
NO
YES
Yを2ΔY変化
#217
change Y by 2ΔY
全走査完了?
#218
scan all completed?
NO
YES
END
#219
A

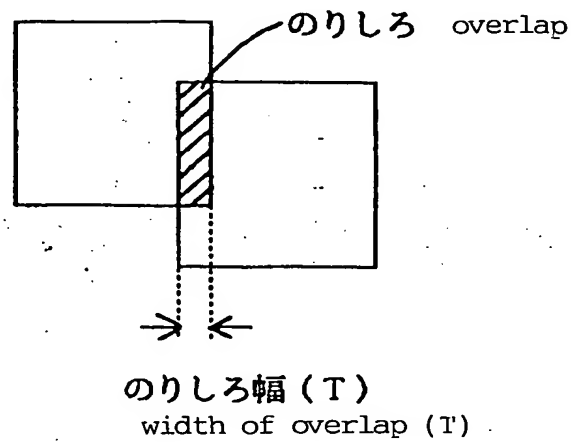
【図１２】
Fig. 12



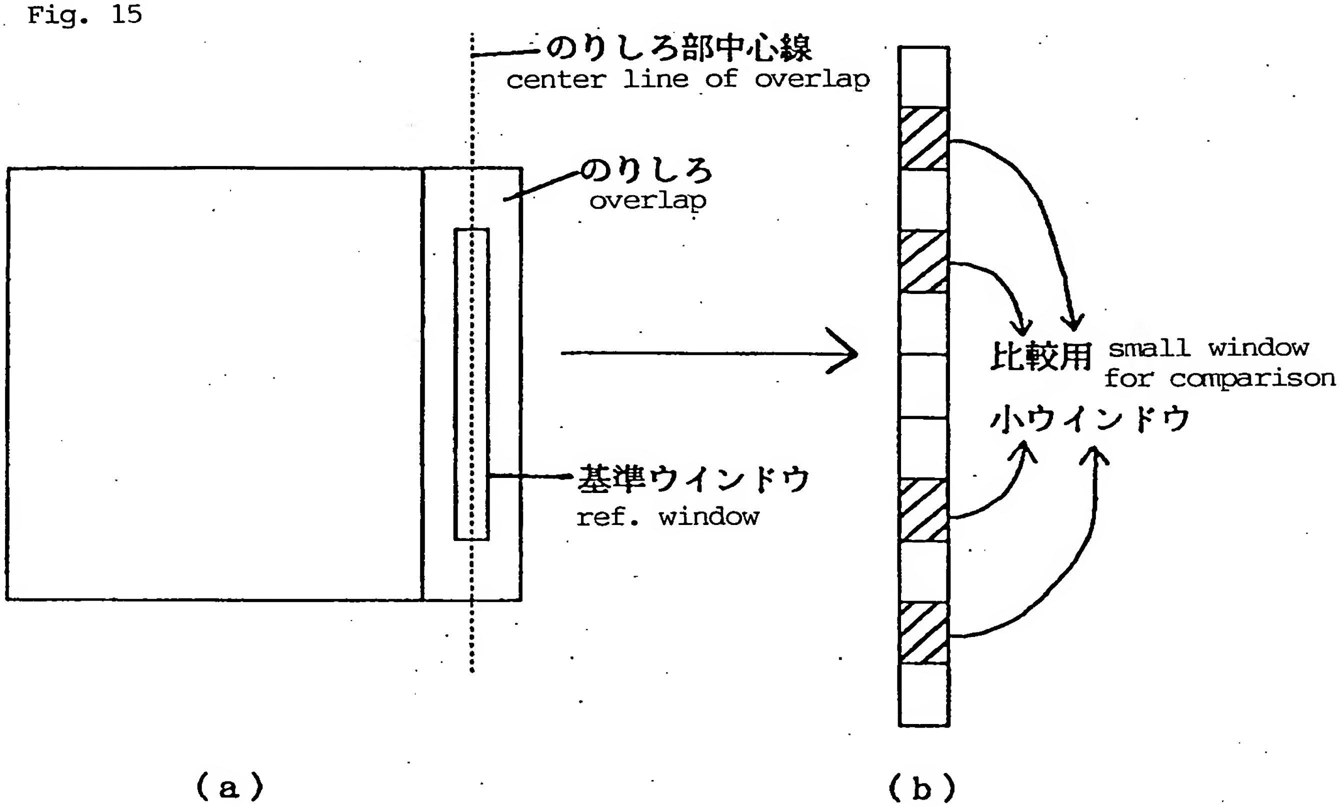
【図13】
Fig. 13


2次元カラー画像
3次元データ
焦点距離
基準面距離
#301
2-dimensional color image
3-dimensional data
focal length
distance to reference plane
2次元カラー画像からの接合点探索
#302
search junction point from 2-dimensional color image
2次元画像接合点と焦点距離、基準面距離からカメラ回転角を算出
#303
calculate camera rotation angle from junction point of 2-dimensional image, focal length, and distance to reference plane
calculate coordinate conversion parameter of 3-dimensional space from camera rotation angle
カメラ回転角より3次元空間の座標変換パラメータを算出
#304
#305
接合部分のパッチの連続性評価値算出
calculate continuity evaluation value of patch at junction portion
#309
評価値が小さくなる方向に回転角を微小変動させる。
slightly change rotation angle to decrease evaluation value
評価値が一定値以下？
#306
evaluation value within prescribed value?
No
No
繰り返し回数が一定以上？
#308
number of repetition exceed prescribed number?
Yes
Yes
最後に求めた座標変換パラメータをもちいて2つの3次元画像を同一座標系に変換し貼り合わせる
#307
convert two 3-dimensional images to same coordinate by using last calculated coordinate conversion parameter and patch up
終了
#310
end

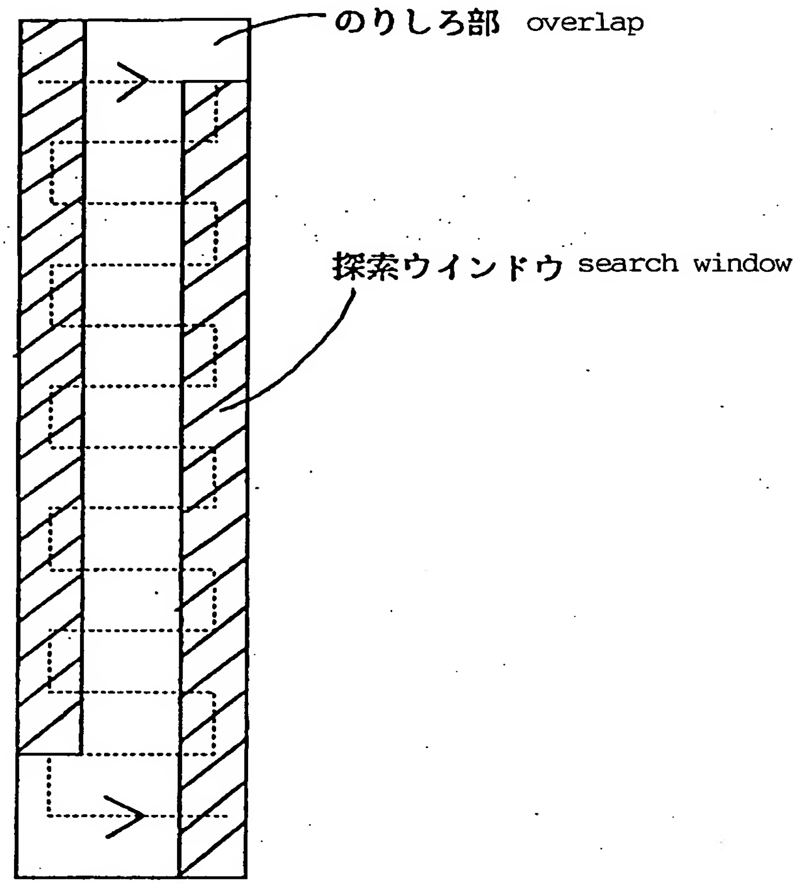
【図１４】
Fig. 14



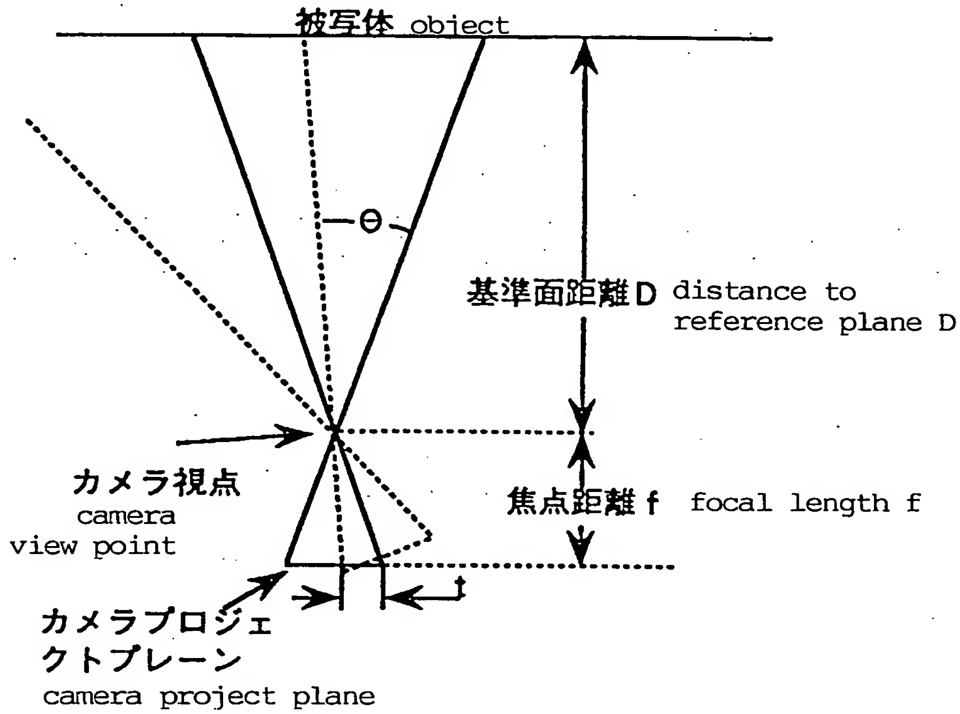

【図１５】
Fig. 15



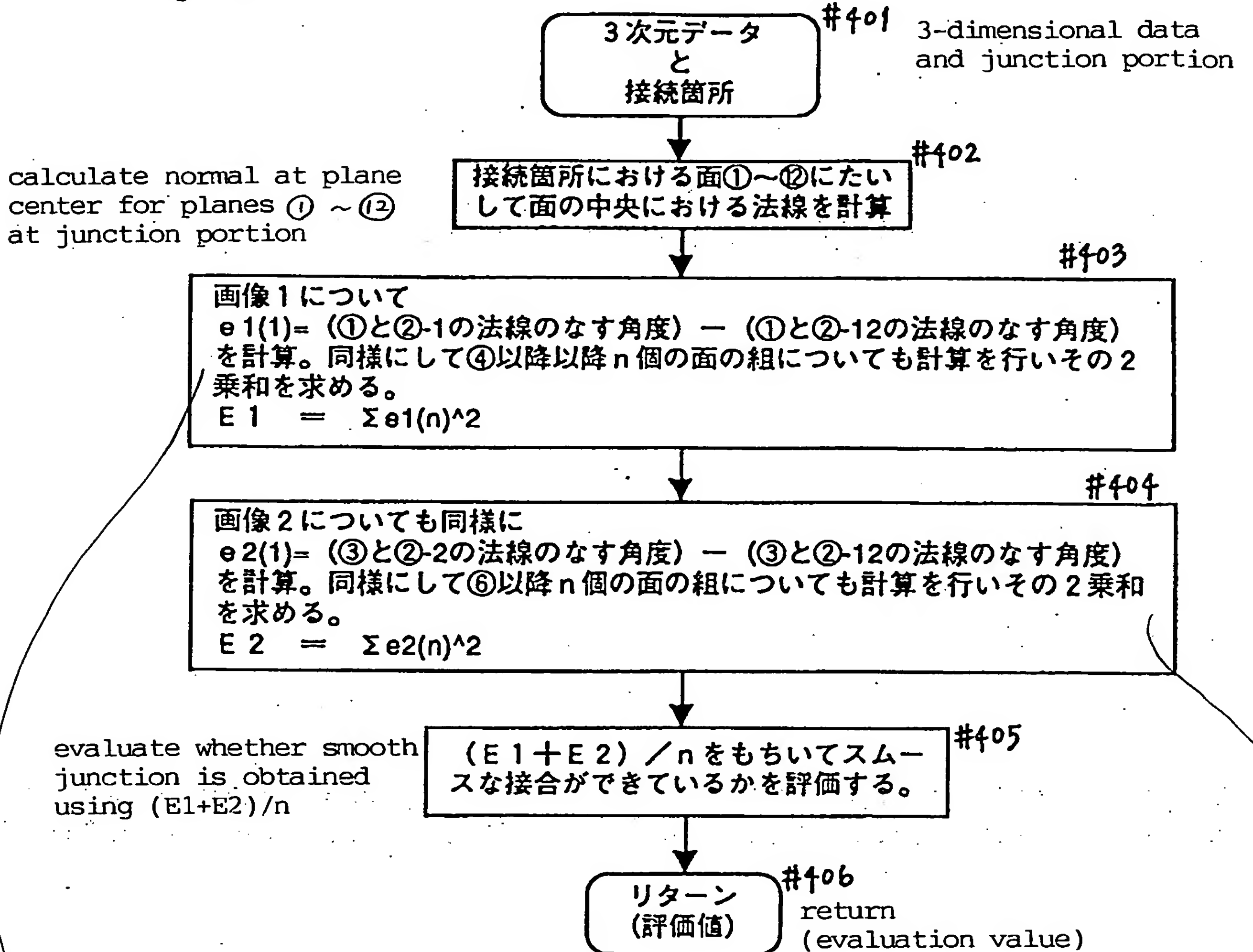
【図１６】
Fig. 16



【図１７】
Fig. 17


被写体 object
θ
基準面距離D distance to reference plane D
カメラ視点
camera view point
焦点距離 f focal length f
t
カメラプロジェクトプレーン
camera project plane

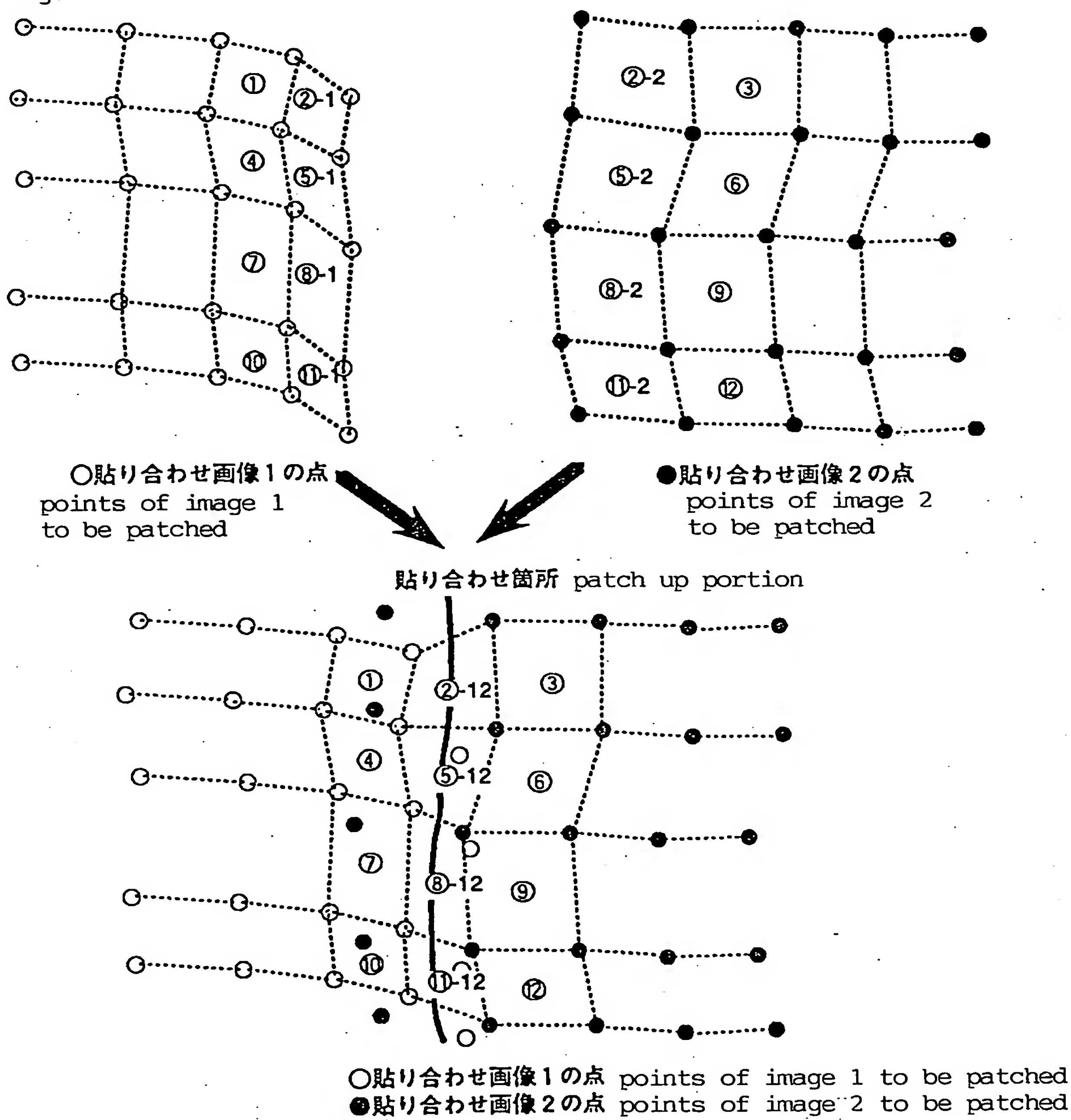
【図１８】
Fig. 18



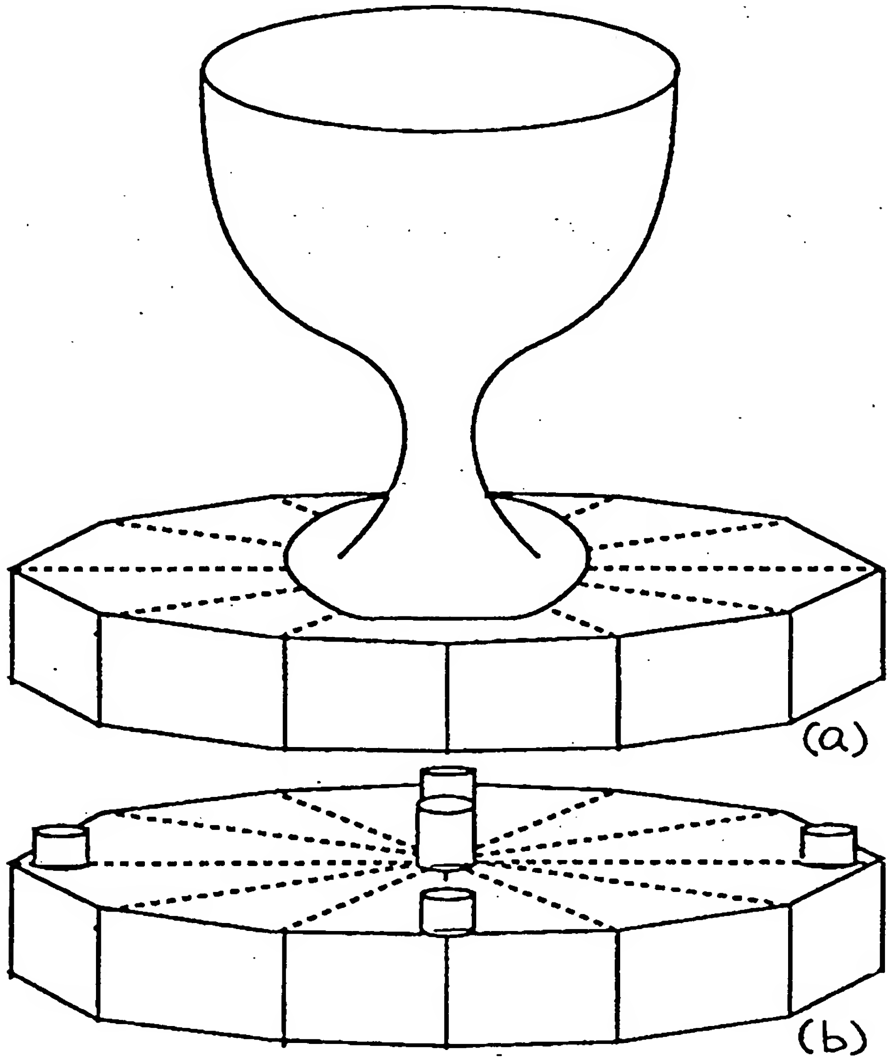

#403
for image 1
calculate e1(1)=(angle formed by normals of ① and ②-1) - (angle formed by formals of ① and ② -12)
similarly, calculate for n set of planes following ④, and calculate square sum.

#404
similarly, for image 2
calculate e2(1)= (angle formed by normals of ③ and ② -2) - (angle formed by normals of ③ and ②-12)
similarly, calculate for n set of planes following ⑥, and calculate square sum.

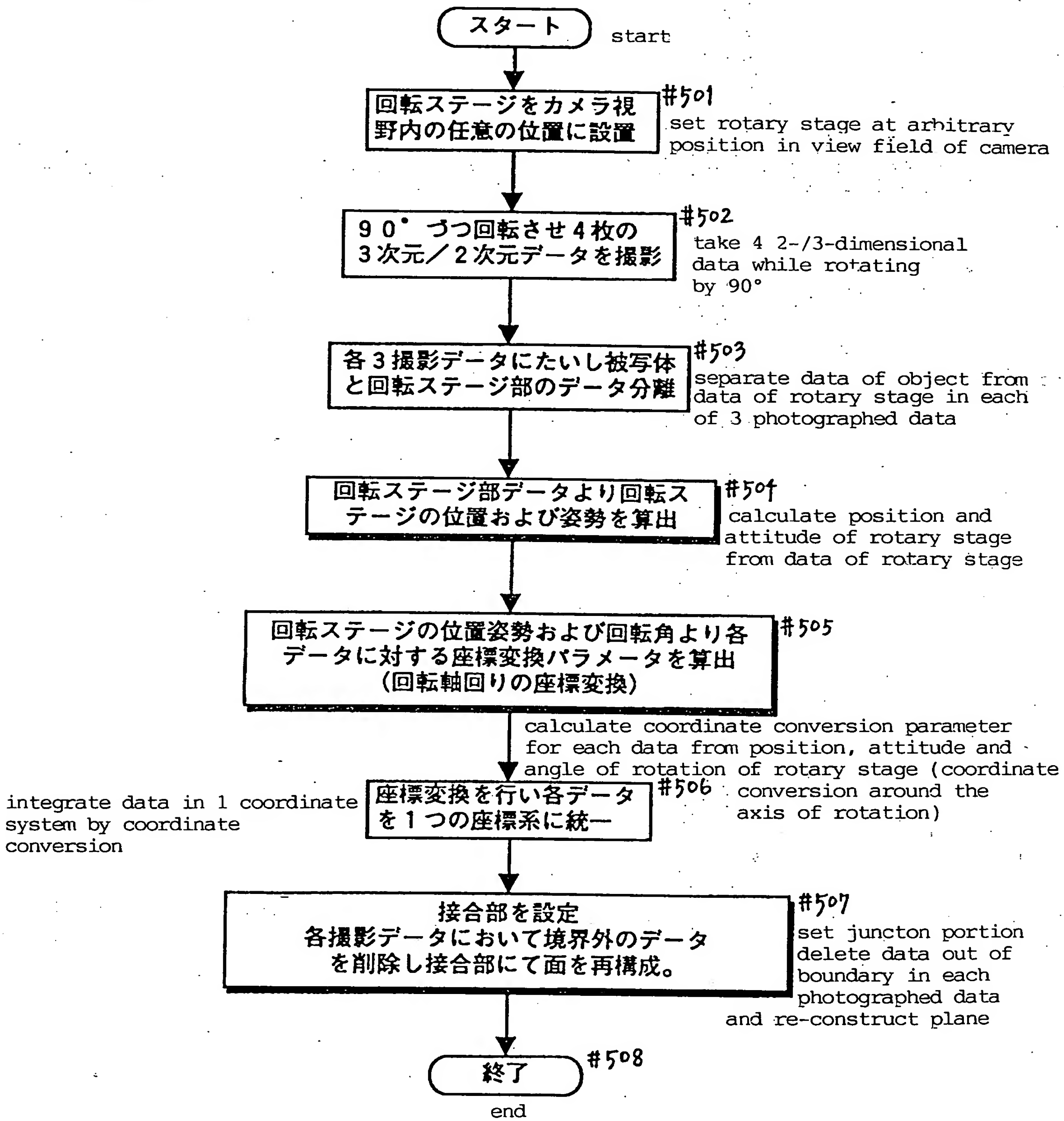
【図１９】
Fig. 19


①
②-1
④
⑤-1
⑦
⑧-1
⑩
⑪-1
②-2
③
⑤-2
⑥
⑧-2
⑨
⑪-2
⑫
○貼り合わせ画像１の点
points of image 1
to be patched
●貼り合わせ画像２の点
points of image 2
to be patched
貼り合わせ箇所 patch up portion
②-12
⑤-12
⑧-12
⑪-12
○貼り合わせ画像１の点 points of image 1 to be patched
●貼り合わせ画像２の点 points of image 2 to be patched

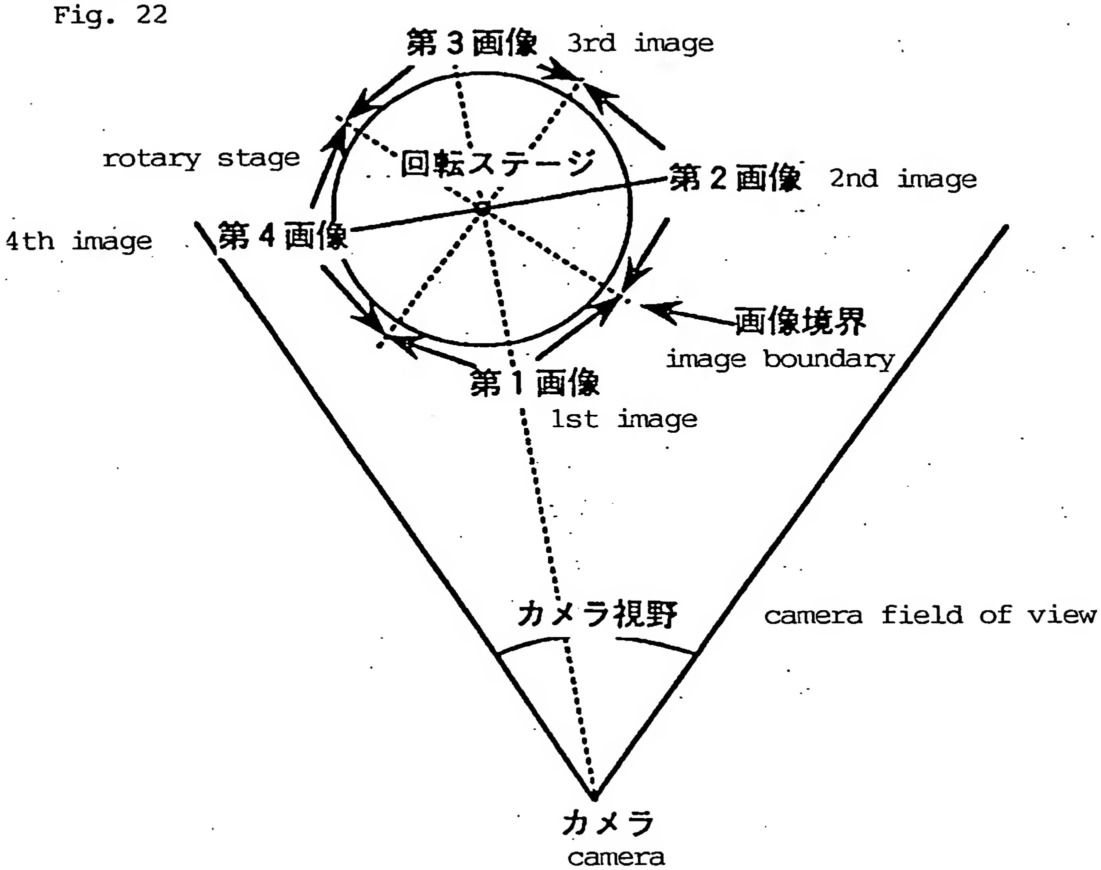
【図２０】
Fig. 20



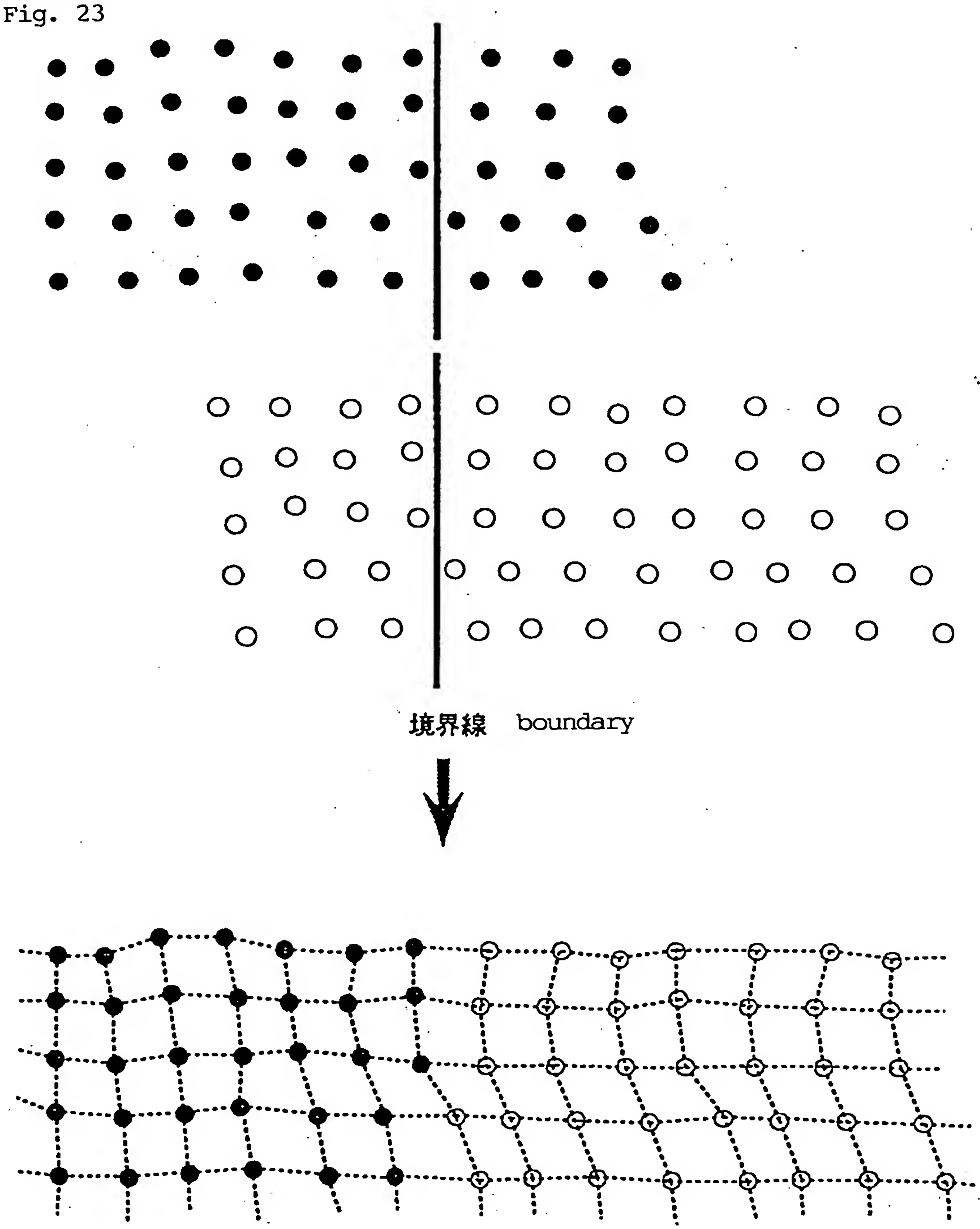
【図２１】
Fig. 21


スタート
start
#501
回転ステージをカメラ視野内の任意の位置に設置
set rotary stage at arbitrary position in view field of camera
#502
９０°づつ回転させ４枚の３次元／２次元データを撮影
take 4 2-/3-dimensional data while rotating by 90°
#503
各３撮影データにたいし被写体と回転ステージ部のデータ分離
separate data of object from data of rotary stage in each of 3 photographed data
#504
回転ステージ部データより回転ステージの位置および姿勢を算出
calculate position and attitude of rotary stage from data of rotary stage
#505
回転ステージの位置姿勢および回転角より各データに対する座標変換パラメータを算出（回転軸回りの座標変換）
calculate coordinate conversion parameter for each data from position, attitude and angle of rotation of rotary stage (coordinate conversion around the axis of rotation)
#506
座標変換を行い各データを１つの座標系に統一
integrate data in 1 coordinate system by coordinate conversion
#507
接合部を設定
各撮影データにおいて境界外のデータを削除し接合部にて面を再構成。
set juncton portion
delete data out of boundary in each photographed data
and re-construct plane
#508
終了
end

【図２２】
Fig. 22

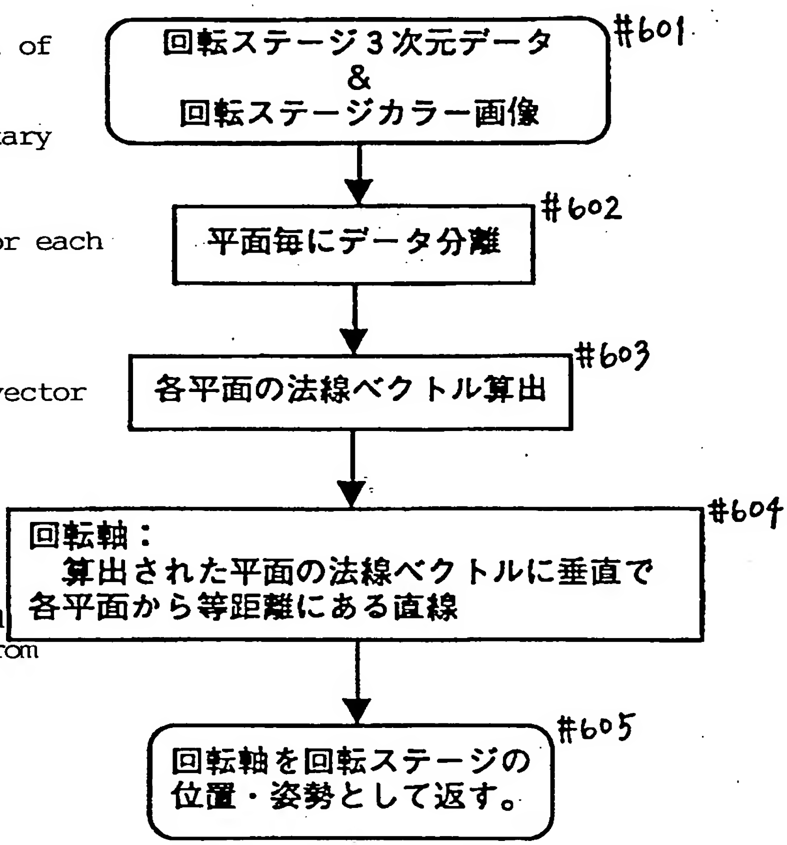

第３画像 3rd image
rotary stage
回転ステージ
第２画像 2nd image
4th image
第４画像
画像境界
image boundary
第１画像
1st image
カメラ視野
camera field of view
カメラ
camera

【図２３】
Fig. 23



【図２４】

Fig. 24




3-dimensional data of rotary stage
&
color image of rotary stage

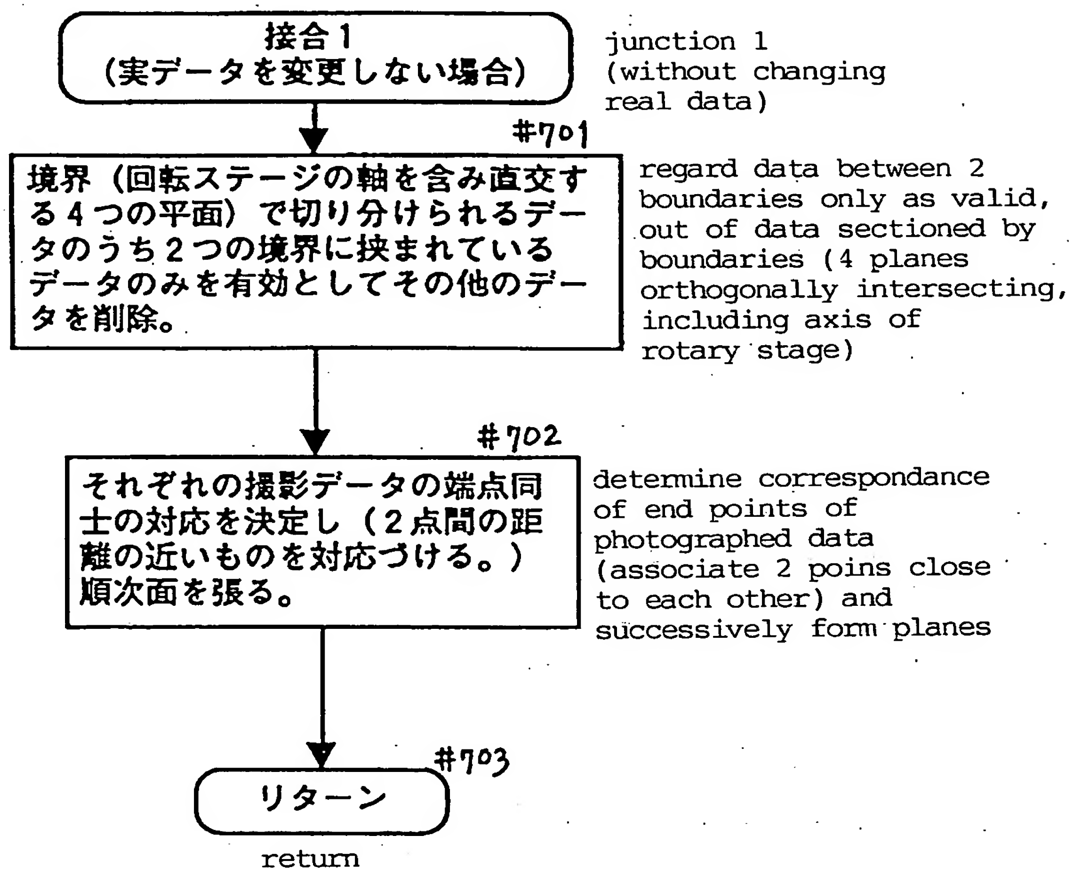
data separation for each plane

calculate normal vector of each plane

rotation axis:
line vertical to normal vector of calculated plane and at equal distance from each plane

return rotation axis as position and attitude of rotary stage

【図２５】
Fig. 25


接合１
（実データを変更しない場合）
junction 1
(without changing
real data)
#701
境界（回転ステージの軸を含み直交する４つの平面）で切り分けられるデータのうち２つの境界に挟まれているデータのみを有効としてその他のデータを削除。
regard data between 2
boundaries only as valid,
out of data sectioned by
boundaries (4 planes
orthogonally intersecting,
including axis of
rotary stage)
#702
それぞれの撮影データの端点同士の対応を決定し（２点間の距離の近いものを対応づける。）順次面を張る。
determine correspondance
of end points of
photographed data
(associate 2 poins close
to each other) and
successively form planes
#703
リターン
return

【図２６】
Fig. 26

接合２
（データを変更しスムースな貼り合わせを行う場合）

junction 2
(for smooth patch up with change of data)

#801

２つの撮影データにたいし境界（回転ステージの軸を含み直交する４つの平面）からの距離で対応点を決定。

determine corresponding points based on distance from boundary (4 planes orthogonal to each other, including axis of rotary stage)

#802

境界から一定範囲のデータに対して対応する２点から新たな１点を生成。（境界からの距離に応じて生成するポイントを決定。）
・境界からの一定範囲の距離をＤとし、２点をＸ１、Ｘ２（Ｘ１が境界の内側、Ｘ２が境界の外側、境界からの２点の平均距離をｄとする）とし新たな点をＸ３とすると
Ｘ３＝((Ｄ＋ｄ)＊Ｘ１＋(Ｄ－ｄ)＊Ｘ２)／２Ｄ
となる。

generate new 1 point from corresponding 2 points for data in prescribed scope from boundary (determine point to be generated based on distance from boundary).
X3=((D+d)*X1+(D-d)*X2)/2D
where D denote distance of prescribed scope from boundary, X1, X2 denote 2 points (X1 in boundary, X2 out of boundary, average distance of 2 points from boundary being d).

#803

境界付近は新たに生成したデータをそれ以外は実データを用いて面を再構成。

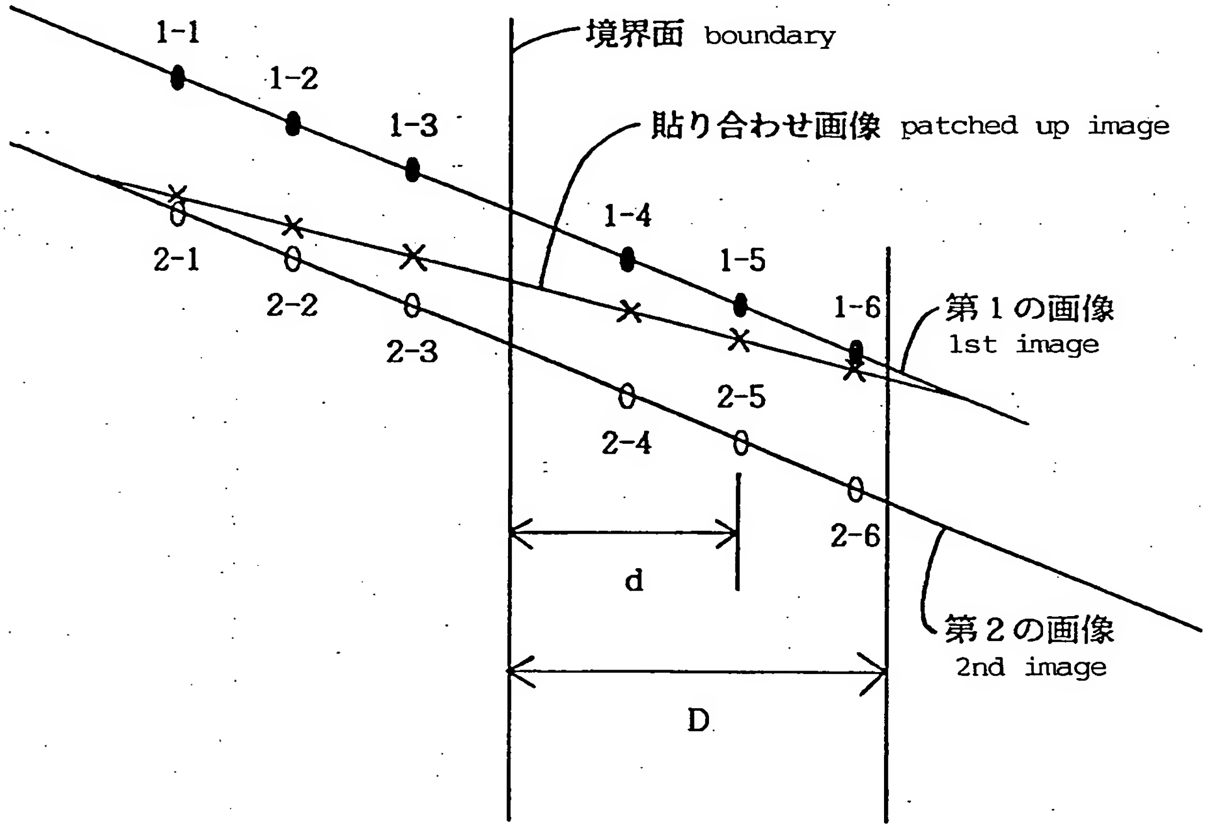
near boundary, use newly generated data, otherwise use real data for re-constructing plane

#804

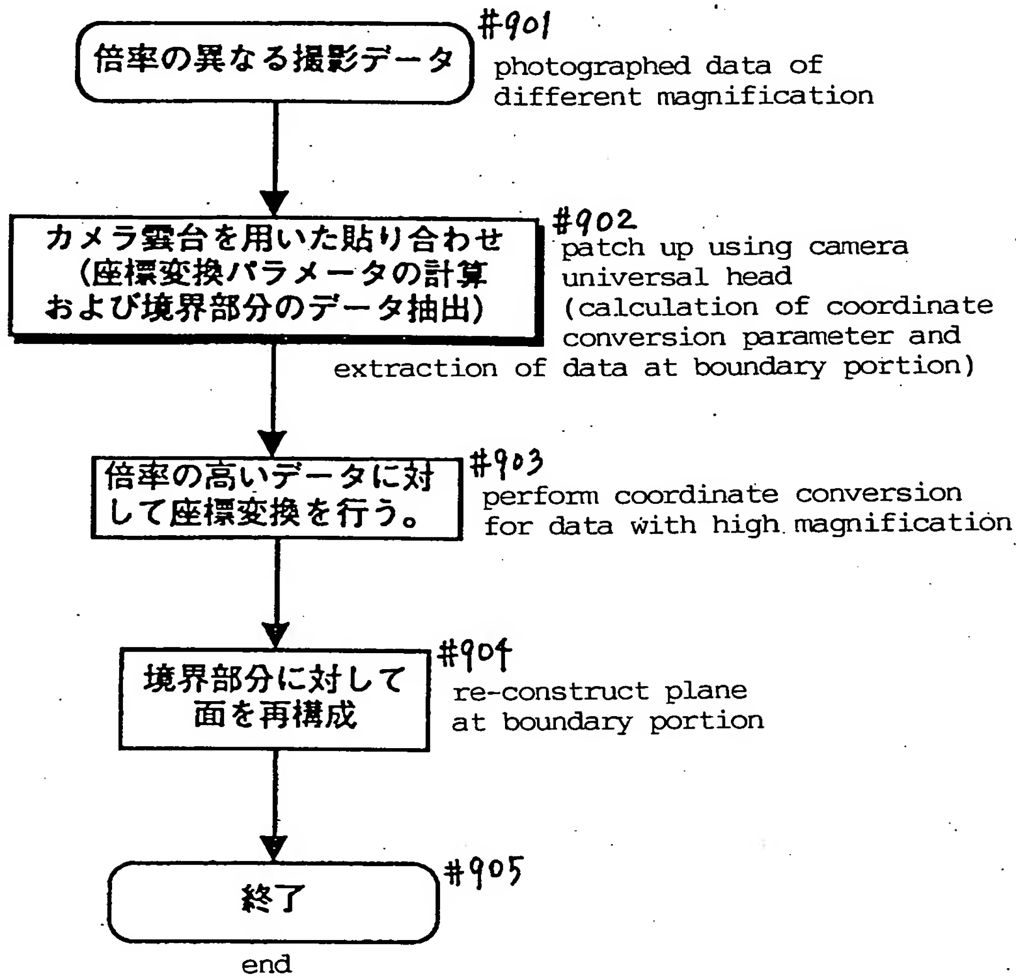
リターン

return

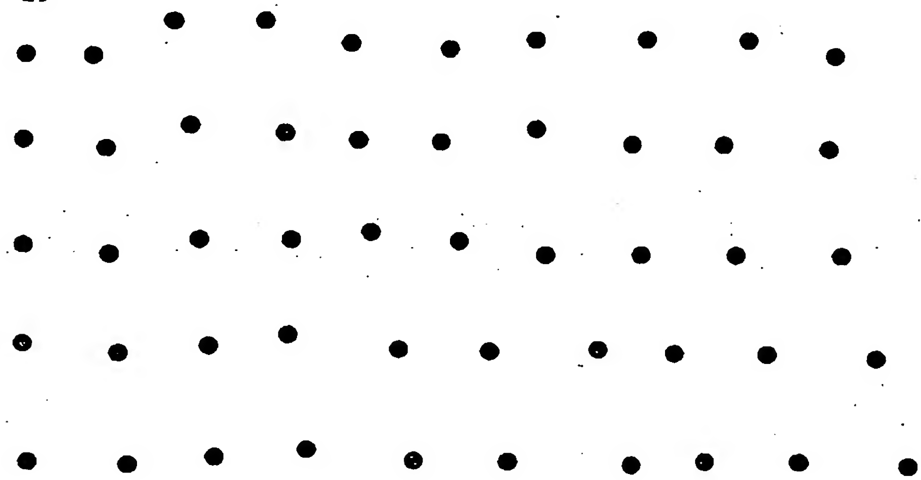
【図２７】
Fig. 27


1-1
1-2
1-3
1-4
1-5
1-6
2-1
2-2
2-3
2-4
2-5
2-6
境界面 boundary
貼り合わせ画像 patched up image
第１の画像
1st image
第２の画像
2nd image
d
D

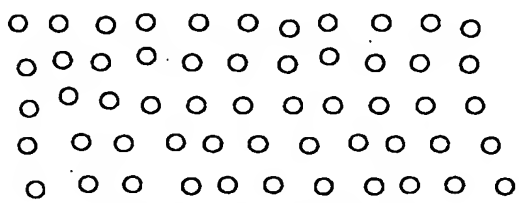
【図２８】
Fig. 28


倍率の異なる撮影データ
#901
photographed data of
different magnification
カメラ雲台を用いた貼り合わせ
（座標変換パラメータの計算
および境界部分のデータ抽出）
#902
patch up using camera
universal head
(calculation of coordinate
conversion parameter and
extraction of data at boundary portion)
倍率の高いデータに対して座標変換を行う。
#903
perform coordinate conversion
for data with high magnification
境界部分に対して
面を再構成
#904
re-construct plane
at boundary portion
終了
#905
end

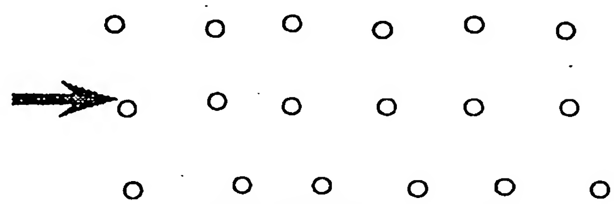
【図２９】
Fig. 29



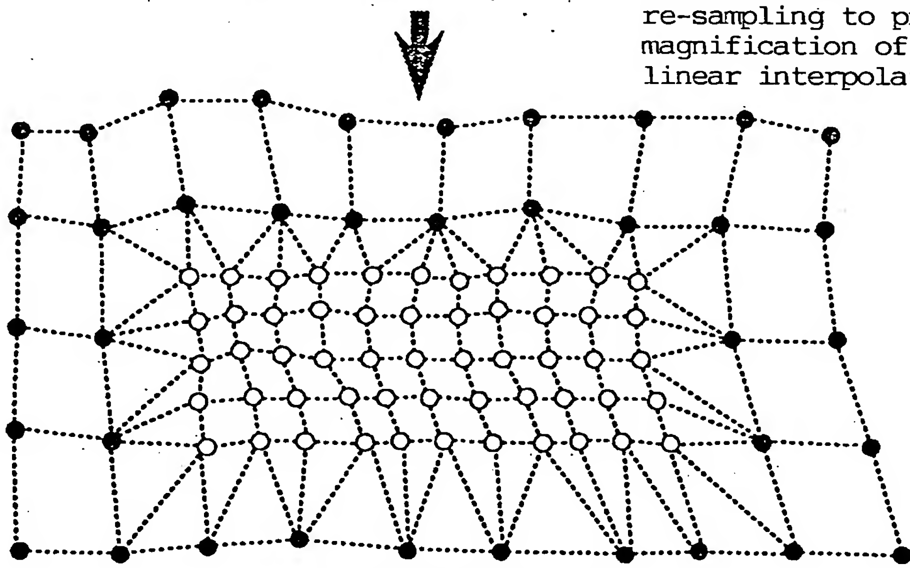
３次元データ１（倍率Ｎ１）(a)
3-dimensional data 1 (magnification N1)



３次元データ１（倍率Ｎ２）(b)
3-dimensional data 1 (magnification N2)

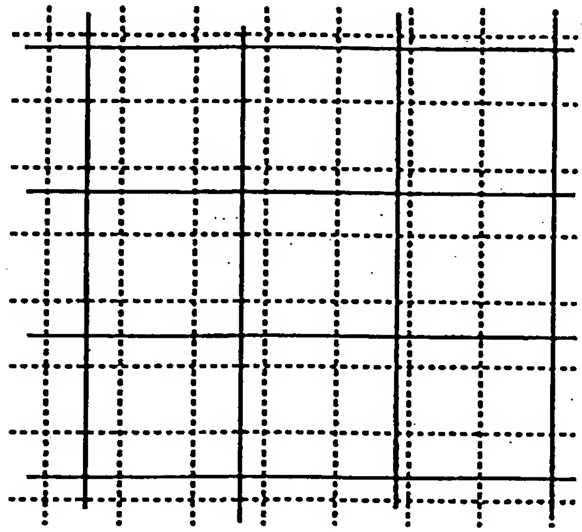


線形内挿で倍率Ｎ１になるようにリサンプリング (c)
re-sampling to provide magnification of N1 by linear interpolation

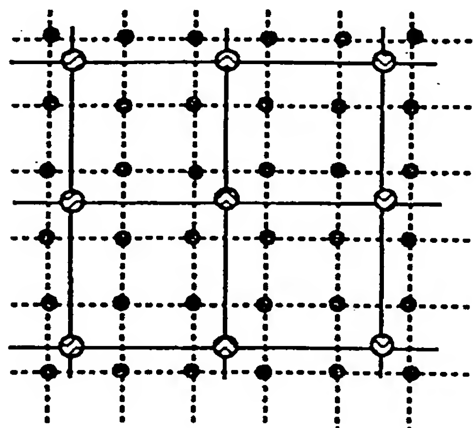


貼り合わせ結果 (d)
result of patch up

【図３０】
Fig. 30



【図３１】
Fig. 31



[Document Name] Abstract

[Abstract]

[Subject] To perform image patch up at a relatively low cost, by inputting a plurality of pieces of image data from multiple viewpoints, calculating relative positions of the input images, and obtaining a conversion parameter of the image data for performing the patch up.

[Solving Means] The image input camera of the present invention includes input means for inputting image data of an object, means for calculating, from a plurality of pieces of the image data input from multiple viewpoints, a coordinate conversion parameter for patch up of the plurality of pieces of the image data, and means for patching up the plurality of pieces of the image data.

[Selected Drawing] Fig. 13